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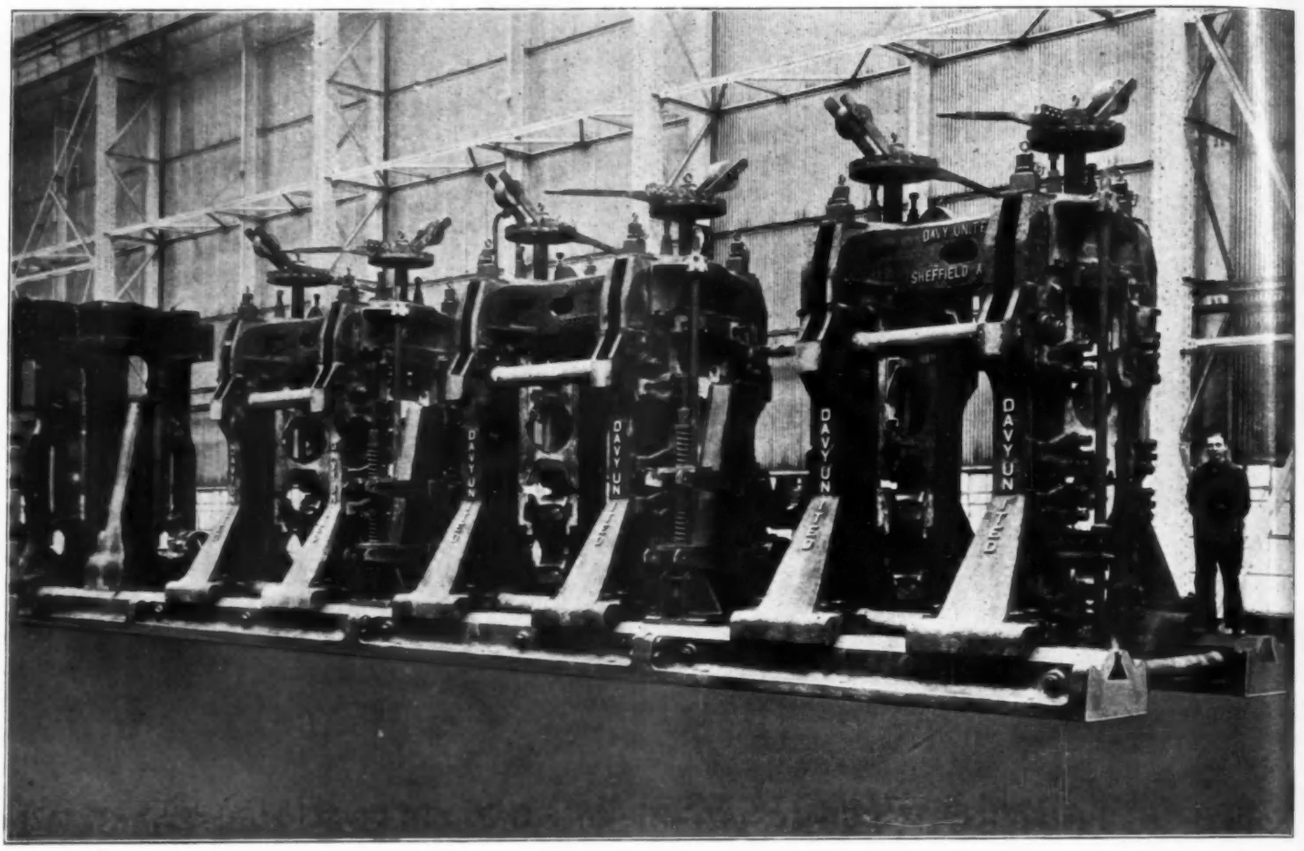

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THE CONTROL OF POWER IN LARGE INTER-CONNECTED ELECTRIC SUPPLY SYSTEMS.

By T. F. WALL, D.Sc.

(*Continued from page* 44.)

THE ELECTRIC ARC.

§15: *Mechanism of the Arc.*—When a circuit-breaker is opening, the arc current will pass through zero at the end of the half-cycle and the problem of the designer is to prevent the arc re-igniting as the voltage across the switch contacts increases. This problem embraces the requirements on the one hand, that the insulating property of the space between the circuit-breaker contacts shall be established with the highest possible speed, and, on the other hand, that the gap between the switch contacts shall also increase at the highest possible speed. The insulation of the gas-filled space between the switch contacts when opening a circuit depends upon the type of break employed. In Fig. 28, herewith, the curve I shows, as a standard of reference, the insulation strength for clean, dry air, at atmospheric pressure and at a temperature of 15 deg. C. Curve II refers to an "expansion" (water) switch, and Curve III refers to an oil circuit-breaker without an explosion pot. It will

Fig. 28.

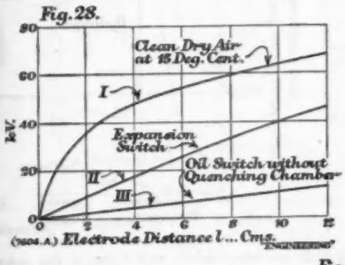


Fig. 32.

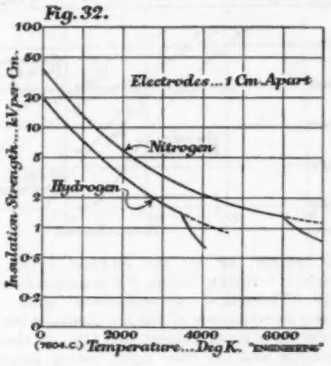


Fig. 29.

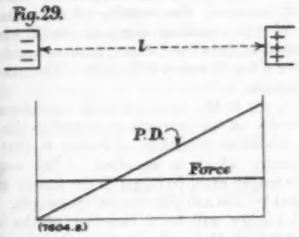


Fig. 30.

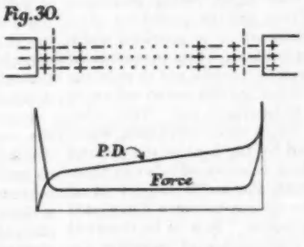
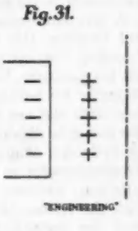


Fig. 31.



be noted, in the case of the oil switch, that the insulation is only a small fraction of that of clean dry air, while the "expansion type of switch has a much closer approach in insulation strength to that of the air. The problem of the circuit-breaker designer is to obtain an insulation strength as nearly as possible equal to that shown by Curve I for dry air, and even to surpass these values. There are two main factors which operate to reduce the insulation strength of the space between the switch contacts, namely, (i) the "space charge" between the electrodes, that is to say, the high electron density which will exist in the space when the switch contacts are being separated; and (ii) the low density of the gas or, what is equivalent, the high temperature in the space, since for constant pressure, a rise of temperature will correspond to a reduction of the molecular and atomic density.

(i) The Electron Density in the Space between the Switch Contacts.—If the electron density is relatively small (that is, less than about 10^9 per cubic centimetre, as is further explained below), then, when a p.d. is applied across the contacts, the pressure gradient $\frac{dV}{dx}$ will be constant; *i.e.*, the force F (which is numerically equal to this pressure gradient) will also be constant, as shown in Fig. 29, above. If, however, a space charge of appreciably greater magnitude than this critical value exists in the gas, an applied p.d. across the gap will cause the electrons to move towards the anode and the ions to move towards the cathode, thus causing a local distortion of the field in the neighbourhood of the anode and the cathode, respectively. As a result, there will be a corresponding increase in field strength near the electrode surface, as is shown in Fig. 30; and, since the electrons will move much more rapidly than the ions, owing to their smaller mass, the ions will remain much longer in the neighbourhood of the cathode than the electrons in the neighbourhood of the anode. The relationship between the field strength F, measured in kV per centimetre, and the electron density n of the electrified particles can be found by means of the following simple calculation.

In Fig. 31 are shown diagrammatically the cathode and its neighbouring space charge. The capacitance will be

$$C = \frac{1}{4\pi \times 9 \times 10^{11}} \text{ farad} \left\{ \begin{array}{l} \text{per centimetre depth of the space charge and per square centimetre of the cathode surface.} \end{array} \right.$$

From the curve III, Fig. 28, it is seen that the insulation strength for an oil-switch gap is 1 kV per centimetre, so that the corresponding quantity of electricity in the space charge, where the force (that is, the pressure gradient per centimetre) is about 1 kV, will be

$$Q = V_g \cdot C = \frac{1{,}000}{4\pi \times 9 \times 10^{11}} \text{ coulombs.}$$

But 1 coulomb $= \frac{10^{19}}{1 \cdot 59}$ electrons, so that the density of the space charge will then be

$$n = \frac{Q \times 10^{19}}{1 \cdot 59};$$

that is,

$$n = \frac{1{,}000 \times 10^{19}}{4\pi \times 9 \times 10^{11} \times 1 \cdot 59} = 0 \cdot 56 \times 10^9 \text{ electrons per cubic centimetre} \quad . \quad . \quad (4)$$

It is seen, therefore, that an electron density of about 10^9 per cubic centimetre will produce a distortion of the field strength in the neighbourhood of the cathode of about 1 kV per centimetre, and this will be sufficient to initiate the re-striking of the arc. In order to ensure that the arc will not re-strike, the space charge density should be less than 10^8 per cubic centimetre.

(ii) The Temperature in the Space between the Switch Contacts.—The effect of temperature on the break-down strength of air and hydrogen gas is shown in Fig. 32, above. The sudden change in the curvature in each case is due to dissociation setting in; for hydrogen gas at 3,500 deg. K., and for nitrogen gas at 6,000 deg. K. It is to be observed here that in almost all switches the gas pressure immediately after the arc has become extinguished is greater than the atmospheric pressure.

When an arc ignites, energy is transformed from the electric mains supply system into the heat of the arc, and it is necessary to consider how this transformation of energy is actually achieved. The primary means for the transformation is the electric field which is established across the space between the circuit-breaker contacts. The only way, however, by which this field can operate is by its action on the electrons and the ions; actually, the dominant share in this energy transformation is taken by the electrons, on account of their smaller mass and correspondingly higher speed. The impact of the travelling electrons on the atoms and molaclues transfers a certain amount of kinetic energy to the gas in this way; but the amount of this transfer can only be relatively small and for a long time it was an obscure problem, how the travelling electrons could account for the rise of temperature of the gas. It is now known that a definite distinction must be made between the temperature of the electrons and the temperature of the gas. A further method of energy transfer is the radiation of the atoms which are excited by the electron impact. Fig. 33, on page 82, shows the relationship between the electron temperature, the radiation temperature, and the gas temperature, respectively, during the development of the break-down of the insulation strength of the gas in the space between the circuit-breaker contacts.

When a p.d. is applied to the electrodes, the electrons become accelerated by the field and the electron temperature rises at a very high rate to a peak value, whereas the temperature of the gas molecules remains practically unaltered. This stage comprises the initiation of a glow discharge (that is, "ignition"), and is characterised by low gas temperature and high electron temperature. The gas temperature will now begin to rise, while the temperature due to atomic excitation, as well as the electron temperature, will fall. This stage of the process comprises the development of the glow discharge. The gas temperature will then continue to rise and the electron temperature will fall, as well as the radiation temperature, until the glow discharge changes into an arc discharge, when the current density of the glow reaches its limiting value, as has been considered already in the foregoing. (See also §§5 and 6, page 2, *ante*). The temperatures of the three systems then approach a common value.

The methods for reducing the electron density and increasing the gas density and so increasing the difficulty of ignition may be considered under three heads, namely, (*a*) promotion of the re-union of the electrons and ions, (*b*) the adhesion of the electrons to the walls of the arc chamber and to the atoms and molecules of the gas, and (*c*) electron diffusion. As regards (*a*) and (*b*), it may be said that there is little exact knowledge available, although investigations in these directions are in progress. As regards the method of "electron diffusion," (*c*), this is relatively well understood, and will now be considered in some detail.

The density of the electrons and ions in the core of the arc is relatively high, so that electron diffusion can take place radially outwards; in this way, an electric field is established by means of which the ions are drawn out of the core of the arc. The electron diffusion is defined by the equation,

$$\frac{dn}{dt} = \frac{10}{\pi \frac{d^2}{4}} b^+ \cdot V_e \cdot n \quad . \quad . \quad . \quad (5)$$

where

d is the diameter of the core of the arc,
b^+ is the movement of the ions, and
V_e is the speed of the electrons in volts.

This equation shows that the amount of the diffusion is inversely proportional to the square of the diameter of the core of the arc.

Fig. 34, page 82, shows the rates of diffusion for arcs in hydrogen gas and nitrogen gas, respectively. Arcs of three different diameters are considered, namely, $d = 1$ mm., 2 mm., and 3 mm., respectively. For example, suppose that, when the arc current passes through its zero value as the arc contacts are being separated, the electron density is 10^{16} per cubic centimetre: then, for an arc of 3 mm. diameter in air, the time taken for the electron density to fall to the safe critical value of 10^9 will, in general, be so great that the space will not be sufficiently de-ionised to prevent the arc from

POWER CONTROL IN ELECTRIC SUPPLY SYSTEMS.

Fig. 33.

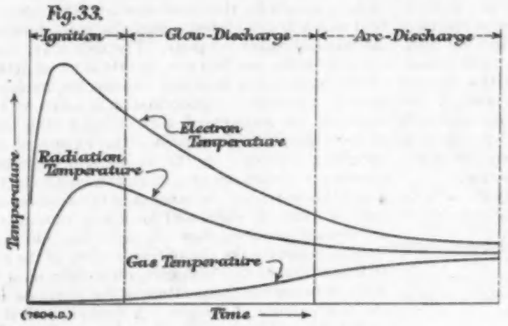
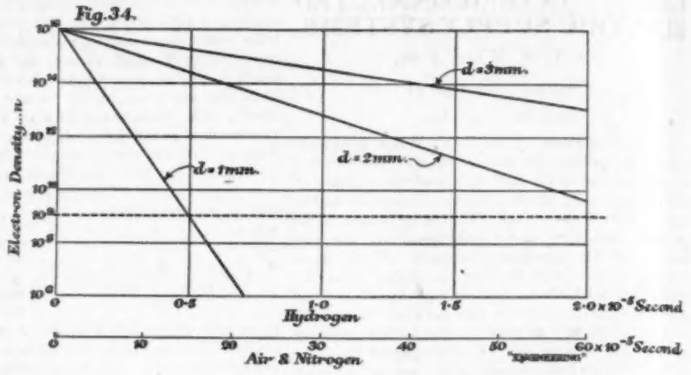


Fig. 34.



re-striking. Next, considering an arc of 2 mm. diameter in hydrogen gas, the critical election density of 10^9 will be reached in about 2×10^{-5} second, whereas the time permissible for the de-ionisation for a 50-frequency supply is of the order of 10^{-4} second. For an arc of 1 mm. core diameter in hydrogen, the critical value of the electron density of 10^9 will be reached in about 5×10^{-6} second. These data show that small-diameter arcs in hydrogen gas are immensely more favourable for interruption without risk of re-striking being incurred, while it is to be observed that both theory and experiment show that, for a given current, an arc in hydrogen gas will automatically burn with a much smaller diameter of core than an arc in nitrogen or air (see also §18).

When the current of small-diameter arcs in hydrogen gas passes through the zero value, the time of de-ionisation by electron diffusion is so extremely short that it more than counteracts the effect of the re-forming of electrons by the electric field between the electrodes, because, before the electric field can reach an appreciable magnitude, the electrons and ions will have been swept away by diffusion. These electric particles presumably will then be trapped by adhesion to the molecules and atoms of the gas which surrounds the part of the arc. In this connection, it is to be observed that the use of a magnetic blast, as in the De-Ion switch, has the effect of reducing the diameter of the arc. It will also be noted that, for arcs of the same diameter in hydrogen and in air, respectively, the equation (5) shows that, while the rate of diffusion is inherently much greater for hydrogen than for air, this effect is further emphasised by the fact that an arc in hydrogen gas will automatically burn with a smaller diameter than in air.

As regards the method for promoting the final quenching of the arc by increasing the gas density, this effect may be obtained by providing means to increase the gas density at the moment of extinction of the arc or, as is the case in the air-blast switch, by driving a stream of cold compressed air across the path of the arc.

Fig. 35, herewith, shows curves defining the fall of temperature of the path of the arc when the current becomes extinguished. These curves refer to arcs of core diameters of 1 mm. and 2 mm., respectively, for arcs in hydrogen gas and for arcs in air or nitrogen. In each case the diameter D of the surrounding cylindrical shell of the arc is taken to be five times the diameter of the core of the arc. Thus, for an arc of 1 mm. in hydrogen gas, when the current ceases the temperature of the path of the arc will fall from 6,500 deg. K. to 5,000 deg. K. in about 5×10^{-6} second, while, for an arc of the same diameter in air, about 50×10^{-6} second will elapse before the temperature of the arc path has fallen by the same amount. That is to say, the initial rate of fall of temperature for the path of a hydrogen arc is about 10 times greater than is the case for the path of an arc in nitrogen or air.

The conclusion to be drawn from these results is that, in order to quench an a.-c. arc as rapidly as possible, it is essential to reduce the diameter of its path to as small a value as possible, just before the current passes through its zero value. This can be done by the so-called "volume cooling", that is, by means of the "expansion" (water) type of

Fig. 35.

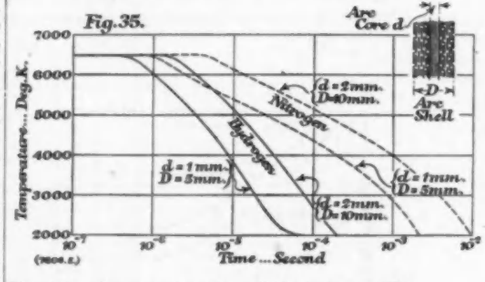


Fig. 37.

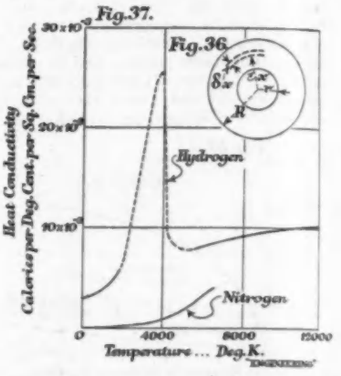


Fig. 36.

circuit-breaker, or by the oil-blast type. This principle of "volume cooling" is considered further in §19. Theoretical investigations show that reducing the diameter of the arc increases its temperature for a given current (see §18), so that the remarkable and, at first sight, rather surprising conclusion is reached that, for the quenching of an a.-c. arc, those conditions are to be provided which will increase the temperature. The operation of "cooling" an arc therefore consists, not in reducing the temperature, but in forcing the arc to reduce its diameter by burning in hydrogen gas. This is the case with the arc in "expansion" switches, where the steam is dissociated by the heat of the arc and an hydrogen atmosphere is obtained, also in those circuit-breakers in which the arc is subject to oil injection, whereby the oil gas becomes dissociated with the release of hydrogen. It is to be observed that the immediate consequence of reducing the diameter of the arc is to increase its temperature.

§16. *Fundamental Equations for the Electric Arc.*—Although all progress in circuit-breaker design must be based upon fundamental experimental data, it is necessary to co-ordinate and interpret such data in the light of theoretical physical considerations. While it is true that there are many gaps in experimental knowledge, the formulation of the results in accordance with known physical principles will provide a basis from which an indication may be obtained as to which direction is most likely to prove most fruitful for further experimental research. The study of the electric arc has been immensely advanced during the past decade and an almost incredibly comprehensive assembly of accurate knowledge has been accumulated in this way. Nevertheless, it remains true that we are still far from possessing a full and satisfactory explanation of the whole sequence of events which occur when a high-power arc is quenched and of the principles according to which this quenching may be realised in a perfectly satisfactory manner.

The current which forms the arc may be expressed by the equation,

$$I = \rho \cdot v \cdot S = E \cdot n \cdot e \cdot b \cdot r \cdot 2\pi = A \cdot E \cdot n_T \cdot r^2. \quad (6)$$

In these expressions, I is the current, ρ is the space charge density per cubic centimetre, v is the velocity of the space charge, and S sq. cms. is the cross sectional area of the arc. E is the potential gradient along the arc, n is the number of electrons per cubic centimetre, e is the electric charge of an electron, b is the speed of the electrons for a potential gradient of 1 volt per centimetre, and r cm. is the radius of the core of the arc. The number of electrons is a function of the absolute temperature T and is denoted by n_T. In what follows, it is assumed that the value of n is a function of T only. The quantity A is a constant.

Equation (6) is the mathematical expression for the continuity of the current throughout the arc. Another condition of stable operation is that the electric energy which is supplied to the arc per centimetre length must be equal to the energy which is dissipated by the arc per centimetre length. The dissipated energy will be a function of the cross-sectional area of the core of the arc and of the temperature; that is to say, for an arc in stable operation,

$$E \cdot I = f(r, T)$$

The relationship between the energy dissipated and the radius of the core of the arc may be expressed approximately by the statement that the dissipated energy is proportional to r^m, where the index m depends upon the means by which the dissipation is accomplished, *e.g.*, the nature of the cooling process which is adopted for cooling the arc. Hence, this energy relationship may be written,

$$E \cdot I = r^m f(T) \quad . \quad . \quad . \quad (7)$$

A further condition which must be fulfilled is that the energy supplied to the arc must be a minimum. That is to say, the arc will so establish itself that, for a given current, the pressure gradient will be a minimum, this requirement being expressed by the equation,

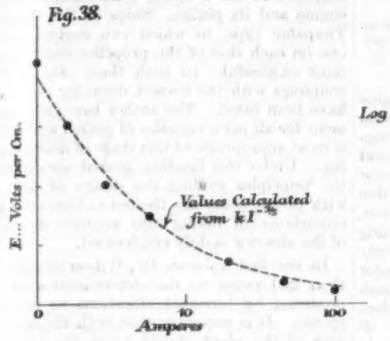
$$\frac{dE}{dT}\Big]_{I = \text{constant}} = 0 \quad . \quad . \quad . \quad . \quad (8)$$

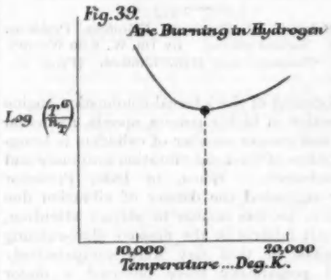
By elimination of r from equations (6) and (7), the following relationship is obtained:

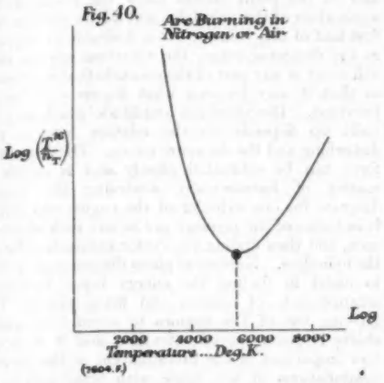
$$I^{\frac{2}{m}-1} E^{\frac{2}{m}+1} = \frac{[f(T)]^{\frac{2}{m}}}{n_T} \quad . \quad . \quad (9)$$

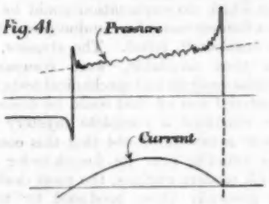
§17. *Relationship between Potential Gradient and Current when the Energy is Dissipated by Conduction to the Surrounding Medium.*—In Fig. 36 is shown the cross section of the core of the arc, having a radius r cms. and of which the temperature is T deg.

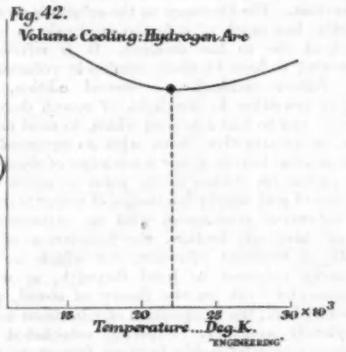
POWER CONTROL IN ELECTRIC SUPPLY SYSTEMS.











absolute, and the boundary of the surrounding medium at the temperature T_0 is shown by the radius R. Heat will be transferred from the core of the arc at temperature T to the surrounding medium by reason of the heat conductivity of the cylindrical shell, of radial thickness $(R - r)$.

If an elementary band be now considered of radius x, radial thickness δx, and 1 cm. in length in the axial direction, the heat conducted across this section will be

$$\lambda_T \frac{2\pi x}{\delta x} \delta T \quad \text{joules per second;}$$

that is,

$$\frac{\lambda_T 2\pi}{\frac{\delta x}{x}} \delta T \quad \text{joules per second,}$$

where λ_T is the heat conductivity at the temperature T, expressed in joules per second $\frac{\text{cm.}}{\text{cm}^2}$ (see Fig. 37).

The total heat energy which will be conducted through this shell will therefore be

$$\frac{2\pi}{\int_r^R \frac{dx}{x}} \int_{T_0}^{T} \lambda_T \, dT \quad \text{joules per second,}$$

that is,

$$\frac{2\pi}{\log_e \frac{R}{r}} \int_{T_0}^{T} \lambda_T \, dT \quad \text{watts;}$$

so that [see equation (7)],

$$E \cdot I = \frac{2\pi}{\log_e \frac{R}{r}} f(T) \quad . \quad . \quad (10)$$

where

$$f(T) = \int_{T_0}^{T} \lambda_T \, dT.$$

For the values of R and r associated with the arc stream, the expression $\frac{1}{\log_e \frac{R}{r}}$ may be taken to be approximately proportional to $r^{\frac{1}{2}}$, so that

$$E \cdot I = k r^{\frac{1}{2}} f(T).$$

That is to say, referring to equation (7), the value of m is $\frac{1}{2}$ for the particular condition of cooling which is now being considered. Substituting this value for m in equation (9) gives

$$I^3 E^5 = \frac{[f(T)]^4}{n_T} \quad . \quad . \quad . \quad (11)$$

For a constant current I, therefore,

$$I^3 \frac{d}{dT} E^5 = \frac{d}{dT} \left\{ \frac{[f(T)]^4}{n_T} \right\}.$$

Now, equation (8) states that, for stable operation,

$$\frac{dE}{dT}\Big]_{I=\text{constant}} = 0,$$

that is, the arc must burn with minimum energy; and since

$$\frac{d}{dT} E^5 = 5 E^4 \frac{dE}{dT}$$

it is seen that E^5 will be a minimum when E is a minimum, that is to say,

$$I^3 \frac{d}{dt} E^5 = 0$$

is the condition for stable operation, or, otherwise stated,

$$I^3 \cdot E^5 = \text{constant}$$

and the potential gradient along the arc is then given by

$$E = \frac{\text{constant}}{I^{\frac{3}{5}}} \quad . \quad . \quad . \quad (12)$$

Fig. 38 shows by the broken-line curve the relationship between the arc pressure gradient E and the current I for various currents; this relationship has been calculated from equation (12). The black circles show the arc pressure gradient E as obtained by actual measurements. This accord between the experimental results and those deduced from the expression (12) provides striking support for the validity of the theoretical treatment.

§18. *Core Diameter of the Electric Arc.*—The cooling conditions which are assumed in this section are those already assumed for the treatment given in §17; that is to say, the arc is assumed to lose its energy solely by conduction to the surrounding medium. Since equation (12) states as a requirement for stable running that, for a given current, the pressure gradient along the arc shall be a minimum, this implies that the right-hand side of equation (9) shall be a minimum, *i.e.*,

$$\frac{[f(T)]^{\frac{2}{m}}}{n_T}$$

shall be a minimum.

The temperature for which this expression is a minimum can be found by direct numerical calculation. Thus, as already stated in §17,

$$f(T) = \int_{T_0}^{T} \lambda_T \, dT,$$

where λ_T is the conductivity of the cylindrical shell of the arc at the temperature T.

(*a*) The Arc is Burning in Hydrogen Gas.—For temperatures which are greater than about 5,000 deg. K., which constitute the significant range for this investigation, the conductivity λ_T may be taken as proportional to $T^{\frac{1}{2}}$, as shown in Fig. 37, so that

$$f(T) \equiv \int \lambda_T \, dT \equiv T^{\frac{3}{2}} \quad . \quad . \quad (13)$$

Further, since the condition of cooling here considered is the radial conduction of the heat from the core of the arc through the hot surrounding shell to the outside cold gas, the index is to be taken as equal to $\frac{1}{2}$, as has been stated already in §17. Hence,

$$\frac{[f(T)]^{\frac{2}{m}}}{n_T} \equiv \frac{[T^{\frac{3}{2}}]^4}{n_T} \equiv \frac{T^6}{n_T} \quad . \quad . \quad (14)$$

Now, the space charge for hydrogen gas at the temperature T deg. K. can be expressed in the form

$$n_T = T^{\frac{1}{2}} \cdot 10^{-\frac{3 \cdot 65 \times 10^4}{T}} \quad . \quad . \quad (15)$$

The temperature for which the quantity on the right-hand side of the expression (14), viz., $\frac{T^6}{n_T}$ becomes a minimum can now be found by plotting the values of this quantity as a function of the temperature. In Fig. 39 the values of $\log\left(\frac{T^6}{n_T}\right)$ have been plotted as function of the temperature, it being observed that, since it is only the minimum value of the curve which is required, the choice of the actual scale used is only a matter of convenience. Fig. 39, herewith, shows that the minimum value of equation (14) for the arc when burning stably in hydrogen gas occurs at about 15,000 deg. K.

(*b*) The Arc is Burning Stably in Nitrogen Gas.—For nitrogen gas (also for air) the heat conductivity λ_T in the range of temperature which is here concerned is about proportional to T^9, so that

$$f(T) \equiv \int \lambda_T \, dT \equiv T^4$$

and, consequently,

$$\frac{[f(T)]^{\frac{2}{m}}}{n_T} \equiv \frac{T^{16}}{n_T} \quad . \quad . \quad . \quad (16)$$

The value of $\log_{10}\left(\frac{T^{16}}{n_T}\right)$ is plotted in Fig. 40, from which it will be seen that the minimum value occurs at a temperature of about 5,500 deg. K.; that is, when the arc is burning in nitrogen gas (or in air), the temperature for a given current is only about one-third of the value when the arc is burning in hydrogen gas. If the pressure gradient E is eliminated between the equations (6) and (7), then

$$r^{m+2} = \frac{I^2}{[f(T)]\, n_T} \quad . \quad . \quad (17)$$

This expression (17) shows that, for a given current, an arc burning with a high temperature of the core will have a smaller radius than an arc which is burning with a low temperature. Consequently, from the results given in Figs. 39 and 40, it will be seen that an arc burning in hydrogen gas will have a much smaller radius of core than an arc burning in nitrogen gas or air.

§19. *Effect of Volume Cooling on the Arc.*—When the arc is cooled, as is the case, for example, in the low-oil content circuit-breaker or the "expansion" (water) type of circuit-breaker, the cooling medium is forced into much more intimate contact with the core of the arc than when the cooling is effected by the natural flow of heat to the surrounding medium

as determined by the heat conductivity of the cylindrical shell which surrounds the core of the arc. In the case now under consideration, the cooling medium, namely, oil or water, is driven in the form of minute drops into the core of the arc and is there vapourised and dissociated so that hydrogen gas permeates the core. Under these conditions, the index m in the equation (7), §16, may be taken as approximately equal to 2 and, by inserting this value in equation (9), it is found that

$$E^2 \equiv \frac{f(T)}{n_T} \quad . \quad . \quad . \quad (18)$$

Under these conditions, therefore, the pressure gradient E is independent of the current strength and further, in order to satisfy the equation (8), *i.e.*,

$$\frac{d\,E}{d\,T} = 0,$$

the gradient E must be constant. The pressure gradient, therefore, will be constant for all values of the current. That this surprising result is in accordance with experimental fact is shown by the oscillogram of Fig. 41, on the previous page, in which it is seen that the gradient of the pressure wave is defined by the slope of the broken straight line and is constant for practically the whole of the current wave, thus confirming the theory.

From equation (17), the high temperature of the arc burning in hydrogen gas involves a correspondingly small radius for the core of the arc. It has been found by actual measurements that, for example, in the case of a 2,000-ampere arc burning in hydrogen gas (that is, as obtained by means of an expansion type of circuit-breaker), the radius of the core of the arc was about 1·5 mm., so that the current density in the core reached the enormous value of over 100,000 amperes per square centimetre.

§20. *The Temperature of the Arc with Volume Cooling.*—As has been stated already in §19, when volume cooling is employed, the index m in equation (7) may be taken to be approximately equal to 2. That this assumption is in accordance with actual practical conditions is shown by the fact that the pressure gradient along the arc is independent of the current strength, as is confirmed by the oscillogram of Fig. 41. Under these conditions of volume cooling, therefore, that is, when the core of the arc becomes permeated with dissociated hydrogen gas, the value of the quantity $[f(T)]^{\frac{2}{m}}$ in equation (9), for $m = 2$, becomes $[f(T)]$. Now the conduction of heat by the cooling medium in this case of the intimate association of hydrogen gas with the arc core is much more effective than that which has been considered in §18, in which λ_T was taken to be proportional to $T^{\frac{1}{2}}$. For example, if λ_T is now taken to be proportional to T^3, then

$$f(T) \equiv \int \lambda_T\, d\,T \equiv T^4 \quad . \quad . \quad (19)$$

so that the temperature will now be defined by the condition that $\frac{[f(T)]^{\frac{2}{m}}}{n_T}$ shall have the value as determined by the expression (19), viz., for $m = 2$, and $f(T) \equiv \int \lambda_T\, d\,T \equiv T^4$, so that

$$\frac{T^4}{n_T} \text{ must be a minimum.}$$

The values of $\log_{10}\left(\frac{T^4}{n_T}\right)$ are plotted in Fig. 42, on page 83, as a function of the temperature T, from which it is seen that the minimum value of this expression occurs at about 20,000 deg. K. This immense temperature involves a correspondingly small diameter of the core of the arc, and a stupendous current density, which may be of the order of 500,000 amperes or more per square centimetre, is consequently involved. From actual experimental measurements it has been found that, for a 2,000-ampere arc, the diameter of the core was 0·75 mm.; and a photograph of the arc showed an almost continuous spectrum, which implies an exceedingly high electron density. For such high current densities, the conditions in the arc are similar to those of a very strong electrolyte.

(To be continued.)

SWAZILAND MINERAL EXPORTS.—Asbestos valued at 67,422*l.*, tin worth 10,729*l.*, and gold of the value of 1,370*l.* were exported from Swaziland, during the quarter ended March 31, 1941.

LITERATURE.

Practical Solution of Torsional Vibration Problems. Two vols. Second edition. By DR. W. KER WILSON. London: Chapman and Hall, Limited. [Price 42*s.* net each.]

THE development of the internal-combustion engine in the direction of higher powers, speeds, reduction in weight and greater number of cylinders is bringing the problem of torsional vibration into more and more prominence. When, in 1895, Professor Dunkerley suggested the danger of vibration due to resonance, he was unable to attract attention, because shaft failures in the massive slow-running steam engines of that day were comparatively rare; but periodically there occurred a major disaster for which no explanation could be found. There was a famous case of a London power station, where the crankshaft failed. The stresses, by all calculation then available, were comparatively low. Chemical analysis and mechanical tests showed that the material was all that could be desired, and the failure remained a complete mystery for 20 years. There is now no doubt that this compound engine was running near its fourth-order critical speed. With modern engines, the most destructive forces are generally those produced by torsional vibrations. The literature on the subject is growing rapidly, but much of it is too academic to be of practical use to the designer. It is refreshing, therefore, to turn to these admirable volumes by Dr. Wilson—nominally, a second edition, but largely rewritten in the light of recent developments—and to find a subject which, to most engineers, is unattractive, dealt with so progressively that anyone having a fair knowledge of dynamics can pursue his studies to the point at which they become of real help in the design of power plants.

The survey commences with an exposition of simple harmonic motion, the foundation of the study of torsional vibration, for which we are primarily indebted to Lord Rayleigh, in whose monumental work on the theory of sound, published in 1877, the composition of vibrations was so laboriously analysed. Having established the fundamental relationship between frequency, stiffness and inertia, Dr. Wilson proceeds to give the calculations for finding the leading natural frequencies for a variety of mechanical arrangements and the development of the corresponding normal elastic curves, including those for aero engines. The typical frequency tabulation tables which are given may be said to show the whole story of the deflections, vibration torques and stiffnesses at all positions where masses are concentrated throughout the shafting system of a plant. The chapter on equivalent oscillating systems is concise but sufficient, and includes the estimation of the moment of inertia of marine and air propellers and the method of estimating the stiffnesses of shafts of various designs. Mention is made of the soap-film method of demonstrating how stiffness is reduced by any departure from the uniform cylindrical shaft, for example, by the presence of a keyway; this reduction in stiffness is more than can be accounted for by the reduction in the modulus of the section. The importance of resilience in this connection is well stated; the maximum safe stress is limited, of course, by the high local stresses which occur with such discontinuities as keyways. The average allowable working stress is therefore greatly lowered compared with that of a plain cylindrical bar; and, since the resilience is proportional to the square of the stress of any part, any local raising of stress greatly reduces the amount of energy which the shaft can store. The mechanism for checking the empirically calculated stiffness of crankshafts is illustrated. The chapter on flexible couplings deals with both the metal and the rubber types, and the necessary calculations are given, with numerous examples.

The chapter on geared systems will be welcome, because geared systems are being increasingly favoured, particularly in marine work. This is because a less bulky high-speed engine can be used with an efficient low-speed propeller. The development for the larger marine plants will probably be in the direction of gearing two, or perhaps four, high-speed engines to a single propeller. The success of this system depends on the phasing of the engines and the coupling connection between each engine and its pinion. Ships of the Mancera and Tuxpanol type, in which two engines are placed one on each side of the propeller shaft, have been most successful. In both these classes, damping couplings with the correct detuning characteristics have been fitted. The author here gives the treatment for all main varieties of geared systems, which is most appropriate at this stage of marine engineering. Under this heading, geared aero engines and the principles guiding the design of aero engines with planet gears are treated extensively, and the importance of taking into account the flexibility of the airscrew is duly emphasised.

In the first volume, Dr. Wilson devotes no less than 250 pages to the determination of stresses produced by torsional vibrations at non-resonant speeds. It is necessary that both the designer and user of the plant should know the result of the application of the principles and advice given in the first half of this volume. It is desirable to forecast, in the designing stage, the vibration stresses that will occur in any part of the crankshaft at any speed, so that it may be seen what degree of safety is provided. The vibration amplitude which may be built up depends on the relation between the disturbing and the damping forces. The disturbing force can be estimated closely and is mainly a matter of harmonically analysing the torque diagram for one cylinder of the engine and giving it in terms of the pressure per square inch of piston area, and then finding the vector summation for all the cylinders. Numerous phase diagrams are given, to assist in finding the energy input for many arrangements of engines and firing orders. The growing use of Vee engines to avoid long crankshafts is given special attention, and it is shown how important is the investigation of the various combinations of Vee angle with firing orders, so that the resultant vector summation for the whole engine shall be as low as possible at the running speed range. Obviously, any arrangement can only give good results at certain speeds, *i.e.*, for certain harmonic orders, and a low summation for one order is at the expense of a high summation for other orders. The effect of phasing airscrew blades relative to engine cranks in direct-connected systems is also dealt with. Although the exciting forces can be estimated, it is a much more complicated problem to estimate the various damping forces which resist vibration. It is not known, for instance, precisely what energy is dissipated by torque variations in propellers, oil films in the engine bearings and hysteresis in the shafting. In the absence of more complete knowledge of damping it is necessary to rely on empirical formulæ based on experience. The method adopted by Dr. Wilson is to find the equilibrium amplitude at the free end of the crankshaft for the energy output, and then, from this angle, to obtain the equilibrium stress at the node in the crankshaft. The equilibrium stress is then multiplied by a dynamic magnifier, which is a function of the material hardness and the equilibrium stress.

The subject of the determination of stresses is so vital that Dr. Wilson devotes a further 200 pages to it in the second volume. After dealing with damping, which depends on the dissipation of energy by internal or external friction, he proceeds to discuss what he terms "apparent damping," which obviates the indefinite growth of amplitudes at resonance by preventing truly resonant conditions from becoming established. He shows that, at strong criticals, the principal damping is due to hysteresis loss, and 75 per cent. of the total dissipation may then be due to hysteresis. In weak criticals, the hysteresis loss may be only one-third of the total loss. There is a very informative table showing where the damping losses take place in a reciprocating engine under strong and weak criticals. Another table lists the hysteresis constants for various qualities of steels; and a diagram shows the damping ratios for the various engineering materials. One interesting observation is that the damping energy ratio for cast iron is much greater than for steel, and that while, for steel, the ratio increases with the stress, it remains almost constant

for cast iron. From this it appears that, in many instances, there will be a reversion to cast iron because of its damping qualities. If a cast-iron shaft is stressed to one-half the fatigue limit, its diameter is only 20 per cent. greater than the diameter of the steel shaft when it is stressed to the fatigue limit. Alloy steels and their suitability for particular uses are dealt with, the point being mentioned that, although alloy steels may be four times as expensive as plain carbon steels, they are often a very good investment when everything is taken into account. The controversy regarding the best compromise between surface hardness and core strength is discussed, and there follows a comprehensive treatment of stress concentrations due to discontinuities, such as those which are unavoidable in a crankshaft, and the effect of grooves, keyways and oil holes. Every designer should take to heart the warnings given by the author in this connection.

The possible vibratory stresses under all conditions of running having been estimated and the concentration factors taken into account, these calculations must be checked by means of reliable vibration-measuring instruments, against the stresses occurring. The author not only describes the principal instruments, but, which is more important, gives guidance regarding their correct use and their limitations, so that the records may be reasonably accurate. On instruments of the Geiger type, for instance, there are natural frequencies in the instrument transmission systems; it is obviously necessary that none of these systems should be capable of excitation by the engine or the instrument will record its own vibrations as well as of those of the engine. However, since there is a choice of instruments, and each can have its natural frequencies altered, it is possible with two instruments to deal satisfactorily with all frequencies up to 6,000 vibrations per minute. A technical description is given of the electrical instruments which are most used for high-speed work, and there is a well illustrated and very necessary section on the analysis of records. Dr. Wilson includes technical explanations of the various damping devices in use, beginning with the method whereby the natural frequency is altered either by altering the stiffness of the shafting or by adding a supplementary mass as far away from the node as possible. There is also the method wherein the supplementary mass is elastically connected to the main system in such a manner that the natural frequencies of the added system alone, and of the main system alone, are equal. This method originated 15 years ago in this country and later was extensively used for oil-engine generator sets. Subsequently it was developed to give an automatic change of natural frequency at critical speeds. This combination was adopted for the Graf Zeppelin after the forced landing at Toulon with four broken crankshafts. This airship afterwards travelled 600,000 miles without further mishap or any alteration to the detuning system. The author gives a thorough explanation of the principles underlying this successful method of damping vibration without the absorption or loss of energy.

A chapter is given on the rotating pendulum damper, that generally consists of a supplementary mass, which in appearance is a link-connected balance weight on the crank web. This mass is kept at its maximum radius by centrifugal force, which is the restoring force for the external vibratory system. The pendulum is tuned to the frequency of the vibration which it is required to damp, and the success of the appliance depends on the accuracy of the tuning and the satisfactory mechanical construction of the bearing parts. Dr. Wilson shows what is required in the design of these absorbers so as to deal with more than one harmonic order, and gives two pages of tuning curves with their frequency equations. The last chapter deals with harmonic analysis, which is very necessary for all records where more than one frequency is prominently involved.

It will be appreciated that this is an unusually comprehensive and thoroughly practical work, which not only forms a most valuable contribution to this branch of engineering, but treats the subject in a way which is attractive to that numerous class of engineers to whom the majority of advanced text-books are generally repellent.

STANDARDISATION OF THE DECLARED CALORIFIC VALUE OF GAS.*

By SIR FREDERICK J. WEST, C.B.E., M.Inst.C.E.

THE freedom bestowed upon gas undertakings by the Gas Regulation Act of 1920 to choose, and to vary, the standard of calorific value of gas sold, most suited to all the conditions under which it was to be supplied, marked a very great advance in the development of the gas industry in this country. But while this freedom of choice is of the greatest value, it should not be permitted to go to the length of such diversity of standards as to interfere with the simplification of appliances or to increase the difficulty of the consumer to understand for what he is paying.

The Board of Trade Return of 1938 dealt with 703 gas undertakings, of which 654 had made declarations of calorific value. The total volume of gas sold was about 303,000 million cub. ft. (exclusive of "gas supplied separately for industrial purposes only"),

Fig. 1.

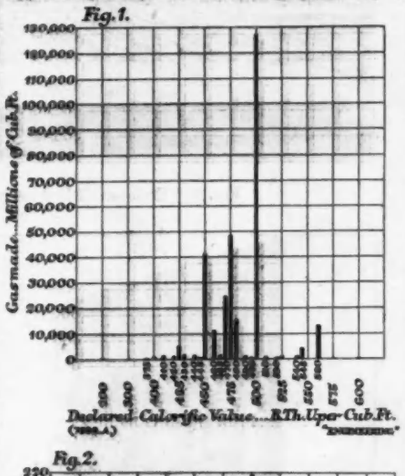
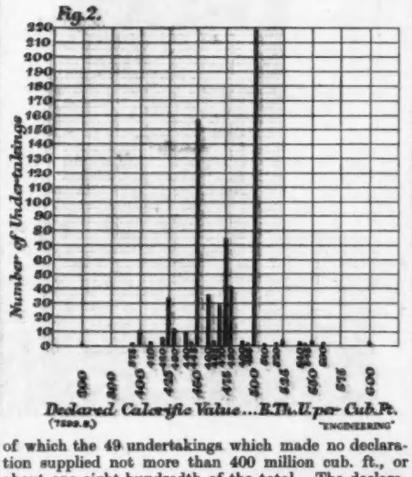


Fig. 2.



of which the 49 undertakings which made no declaration supplied not more than 400 million cub. ft., or about one eight-hundredth of the total. The declarations, which range from 200 B.Th.U. to 600 B.Th.U., are set out in the accompanying Table and the charts shown in Figs. 1 and 2, herewith, in relation both to number of undertakings and volume of gas sold at each value. No less than 26 different calorific values were declared.

Why this diversity? Within the limits of a short paper it is not possible to study in detail all the factors which govern the decision. It is clear that the choice is influenced by the properties of the coal available and the characteristics of the plant employed. Coals which on dry distillation give off gas at a high calorific value will influence the declaration in that direction, while coals which yield a reactive coke lend themselves to "steaming" and the production of large yields at a lower value in suitable plant. The same result can be produced by the combination of water-gas plant with "straight carbonisation." In districts where the selling value of coke is high in relation to the cost of coal, the tendency will be to produce a less volume of gas at a high value, with consequently more coke for sale, in order to produce gas at the lowest possible cost. The influence of existing distribution systems is not to be overlooked, since a low declaration results in the necessity for passing large volumes of gas through possibly inadequate mains, though this difficulty is being increasingly overcome by such devices as high-pressure distribution and ring mains.

In spite of arguments to the contrary, however, it is contended that the policy of the gas industry should be to provide the maximum of refined fuel in the gaseous form, keeping coke in its proper position, the secondary one of a by-product. It is on these lines that the national purposes of coal conservation and smoke abatement will be best served. With regard to both these purposes, some general facts should be borne in mind. Of these the principal are: (i) high gaseous thermal yields per ton of coal carbonised are associated with the lower calorific values; thus, if 72 therms per ton are made at 500 B.Th.U., over 90 therms will be made at 450 in suitable carbonising plant; (ii) save in exceptional market conditions for coke, the therms at 450 can be sold cheaper than those at 500; (iii) by far the best means of achieving the abolition of smoke is by the sale of gaseous therms at a low price. Thus there is good reason why the gas industry should cling to its freedom of choice in the standards to which gas supply is required to conform. The Fuel Research Board, as long ago as 1919, reporting to the President of the Board of Trade, came to the conclusion that there should be no stereotyped standard of calorific value. The Board strongly deprecated the technical staffs of gas undertakings being "compelled to narrow their outlook and limit the exercise of their imagination by the necessity of conforming to a stereotyped standard."

TABLE I.—*Declarations of Calorific Value.*

Declared Calorific Value, B.Th.U. per Cub. Ft.	Number of Undertakings.	Annual Sale in Million Cub. Ft.
200	1	165
375	1	87
400	9	1,023
410	3	1,326
420	6	1,225
425	34	4,781
430	12	2,154
440	10	1,776
445	1	21
450	157	41,365
460	35	11,121
465	3	1,091
470	28	24,707
475	74	48,449
480	41	15,302
490	3	1,520
495	1	13
500	219	127,007
510	1	433
520	1	60
525	4	774
540	2	450
545	1	4,500 (approx.)
550	3	60
560	2	13,192
600	2	83
Total declared	654	302,685
Total undeclared	49	294
Grand totals	703	303,079

Some form of standardisation is of great importance, however, for several weighty reasons. Not the least of these is that of reducing the confusion in the public mind with regard to what the consumer is buying through the gas meter. The public has not accepted the "therm" with any unanimity, and no doubt there are satisfactory reasons why this should be so. Not the least reason for the reluctance of the public to accept the "therm" is that the meter records cubic feet, which must be translated into therms by the use of a factor which varies often from one gas undertaking to another and sometimes from one side of the street to the other. Diversity of standards gives rise to difficulty in the design of burners in gas-fires gas cookers, and other appliances: and diversity of a declared calorific value is not the only difficulty. There remains the problem of diversity of combustion characteristics. It would appear that a sufficient uniformity, in this respect, to enable burners to be reduced to the ultimate simplicity, could only be attained by a gas supply of uniform composition throughout the country—a condition which is obviously an unattainable ideal. But it can be claimed that the standardisation of calorific value, to the extent suggested in this paper, would result in a substantial reduction in the number of standard nipples which manufacturers of, say, cookers, are obliged to carry.

* Paper presented at the 78th annual meeting of the Institution of Gas Engineers, held in London on June 17, 1941. Abridged.

A condition of supply, which has arisen during the present emergency and which may be present to an increasing extent if it is considered desirable after the war to amalgamate undertakings on a geographical basis, is that of interchange between neighbouring undertakings. Uniformity of calorific standard is an obvious advantage under these conditions. Existing cases in which one and the same undertaking is required to give supplies at three different declared values in as many districts must involve difficulties and expense which would appear to be unnecessary and wasteful.

That the subject is not new is evident from a study of the *Transactions* of the Institution and other technical literature. *The Gas Journal*, commenting as long ago as April, 1919, on the Report of the Fuel Research Board of that year, said, "It seems desirable that before any legislation is undertaken the representatives of consumers, producers and makers of fittings and burners should jointly decide on the standardisation of burners in appliances for a limited number of calorific value." The late Sir James Ferguson Bell, in his presidential address of June, 1925, said, "I think there is much to be said for a uniform calorific value—for the whole country. This would simplify the adjustment of gas apparatus and tend to reduce manufacturers' costs." James Jamieson, in his address to the North British Association in 1932, expressed the view that, with average Scottish gas coal, the most economical quality of gas from a production point of view is in the region of 450 B.Th.U.

E. G. Stewart, in his communication to the Institution in June, 1937, observed: "The maker of appliances has at present to cater for a number of calorific values, and accordingly provides gas and air adjustments to cover wide ranges. Such adjustments are capable of abuse as well as use. Closer definition of calorific values would make for more simple burners and should cheapen production. It would not seem out of place, therefore, to expect that in the near future unlimited choice in calorific values will give place to a few standardised values throughout the country, such as 350, 450, 475, 500 and 540. These five would be suitable for any combinations of existing or contemplated means of gas production, whilst the middle three alone should be acceptable to makers of 90 per cent. of the total gas sold, which suggests an even further reduction." T. C. Finlayson, in the discussion of E. G. Stewart's paper, said that the trend (to 450 B.Th.U., 475 B.Th.U. and 500 B.Th.U. gas) was "logical and progressive" and observed that calorific value, if standardised, must bear some relationship to the type of coal most easily obtainable in any given area. C. A. Masterman supported Stewart's view at the same conference. Finally P.E.P., in its *Report on the Gas Industry in Great Britain*, also urged that three standards, which it suggested might be 450 B.Th.U., 475 B.Th.U. and 500 B.Th.U. per cubic foot, should suffice to meet all the different conditions met with in this country.

If, therefore, it be conceded that one standard declared calorific value for the whole country is inadvisable, though in many respects desirable, there appears to be a very strong case for a limited number of standards. It will be seen from a scrutiny of Table I that 500 is the most "popular" value, with 450, 475 and 425 next and in that order. If a margin of 10 B.Th.U. is allowed on either side of these values, we find that 224 undertakings declared at about 500 (*i.e.*, 490 to 510); 203 declared at about 450 (*i.e.*, 440 to 460); 146 at about 475 (*i.e.*, 465 to 485); and 52 at about 425 (*i.e.*, 415 to 435). This makes a total of 625, or 95 per cent. of the total declarations, while the proportion of gas sold at these values to the total volume is of a similar order. It is suggested that these four values, namely, 500, 475, 450 and 425, should suffice to meet very nearly all requirements.

An analysis of the Return shows that about 80 per cent. of the gas supplied by the three Metropolitan and the six principal London suburban companies is sold at a declared calorific value of 500 B.Th.U. per cubic foot, so that this would appear to be a suitable standard for London and the South-East, which represents nearly one-third of the total volume of gas sold in this country. In the provinces, no undertaking with an annual sale of 1,000 million cub. ft. or over is selling gas at more than 500 B.Th.U., while 50 per cent. of the supply in the provinces ranges from 470 B.Th.U. to 480 B.Th.U.; from which one is justified in concluding that the two standards, 500 and 475, should meet the requirements of the provinces. In Scotland the declarations tend to be lower. Edinburgh declares at 500 and Glasgow at 475, but it would be necessary to go to 450 and 425 to meet the wishes of comparatively small Scottish undertakings. These conclusions, therefore, would require modification if benzole washing is to be a permanent and practically universal feature of gas manufacture, and particularly if it is to be carried to the point of reducing effectively the sulphur content of the gas sold. In that case, it would be advisable to adopt a declared value 25 B.Th.U. lower than the standard which would otherwise be adopted.

WELDED TANK SECTIONS FOR 10,000-TON SHIPS.

TODD-CALIFORNIA SHIPBUILDING CORPORATION, RICHMOND, CALIFORNIA, U.S.A.

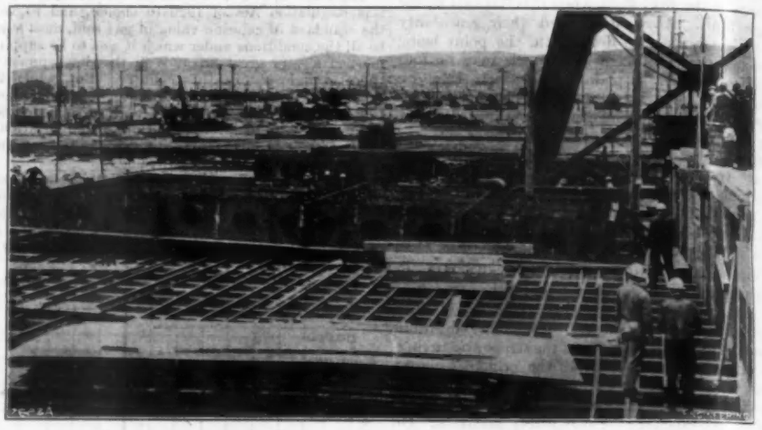


FIG. 1. FINISHED TANK SECTION ON ASSEMBLY PLATFORM.

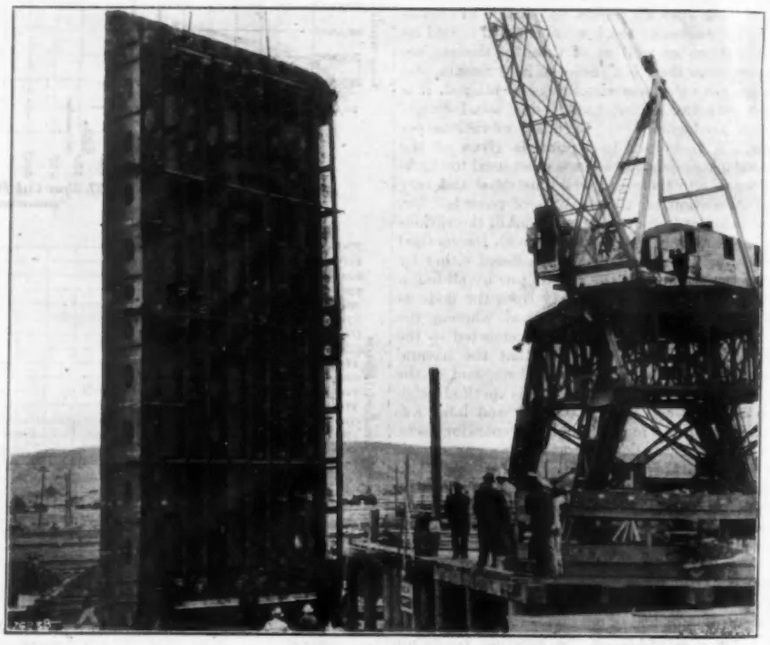


FIG. 2. TURNING OVER TANK SECTION ON ASSEMBLY PLATFORM.

BRITISH SHIPYARDS IN THE UNITED STATES.

IT is announced that the first of the sixty 10,000-ton ships being built in the United States for the British Purchasing Commission is due to be launched on August 15, a striking indication of the speed with which the new shipyards are being brought into production. The two yards are both new. As we have mentioned previously, they are situated on opposite coasts of the United States, one at Richmond, California, belonging to Messrs. Todd-California Shipbuilding Corporation, and one at South Portland, Maine, belonging to Messrs. Todd-Bath Iron Shipbuilding Corporation. Each yard has been commissioned to build 30 of the ships. The following "progress report," based on official information, is illustrated by Figs. 1 to 4, on this and the opposite pages, Figs. 5 and 6, on page 90, and Figs. 7 to 11, on Plate III, the Richmond yard being dealt with in Figs. 1 to 5, and the South Portland yard in Figs. 6 to 11.

Some notes on the Richmond yard, and two aerial views, were given in ENGINEERING of June 20, and it was then observed that very rapid progress had been made in laying out the plant. That this rate has been maintained, if not accelerated, is evident from a comparison of Fig. 5, page 90, with the view, taken from a very similar point, reproduced in Fig. 1, Plate XXXVII, of the June issue referred to above. The earlier view showed that only one of the seven berths was completed at the time. Two were partly completed, and on the other four pile-driving was still in progress. The photograph was taken on April 14, and the corresponding photograph reproduced in this issue some six weeks later. Examination of Fig. 5 will show that, in that period, not only have all seven berths been completed, but in four of them at least part of the bottom plating of the hulls is to be seen on the slipways. Apart from this, the yard itself shows considerable advance, particularly in the region to the rear of the large plate shop at the head of the berths. The waterway at the left of Fig. 5 is seen to be undergoing widening. A careful comparison of the two views will disclose numerous other evidences of activity.

The seven berths, each of which contains a slipway, behind which is a grid-like assembly platform, are separated from one another by crane tracks. The large

Fig. 8. Basin No. 2 under Construction. Berth No. 3 to Right, Berth No. 4 to Left.

Fig. 9. Basin No. 3 under Construction. Berth No. 5 to Right, and Sites for Berths Nos. 6 and 7, at Centre and Left, Respectively.

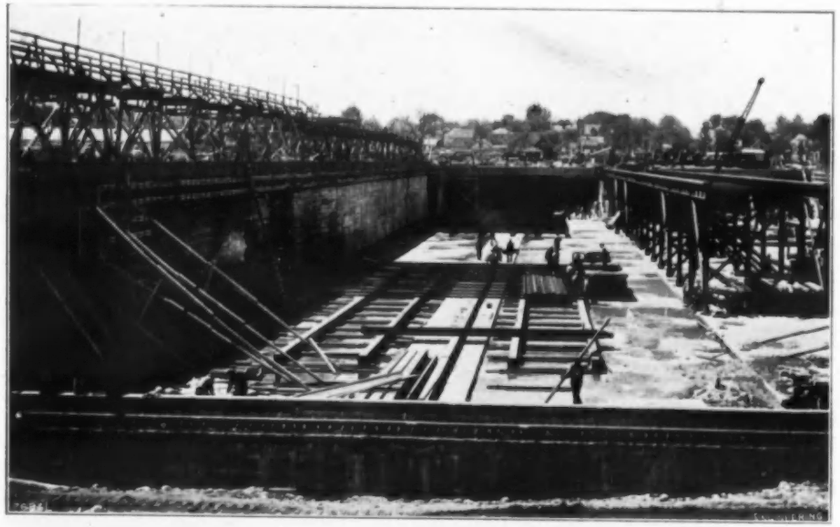


Fig. 10. Berth No. 2 in Basin No. 1 nearing Completion.

Fig. 11. Berth No. 1 in Basin No. 1 nearing Completion.

TODD-BATH IRON SHIPBUILDING CORPORATION SHIPYARD, SOUTH PORTLAND, MAINE, U.S.A.

(*For Description, see Page* 86).

Fig. 7. General View of Yard under Construction, Looking West.

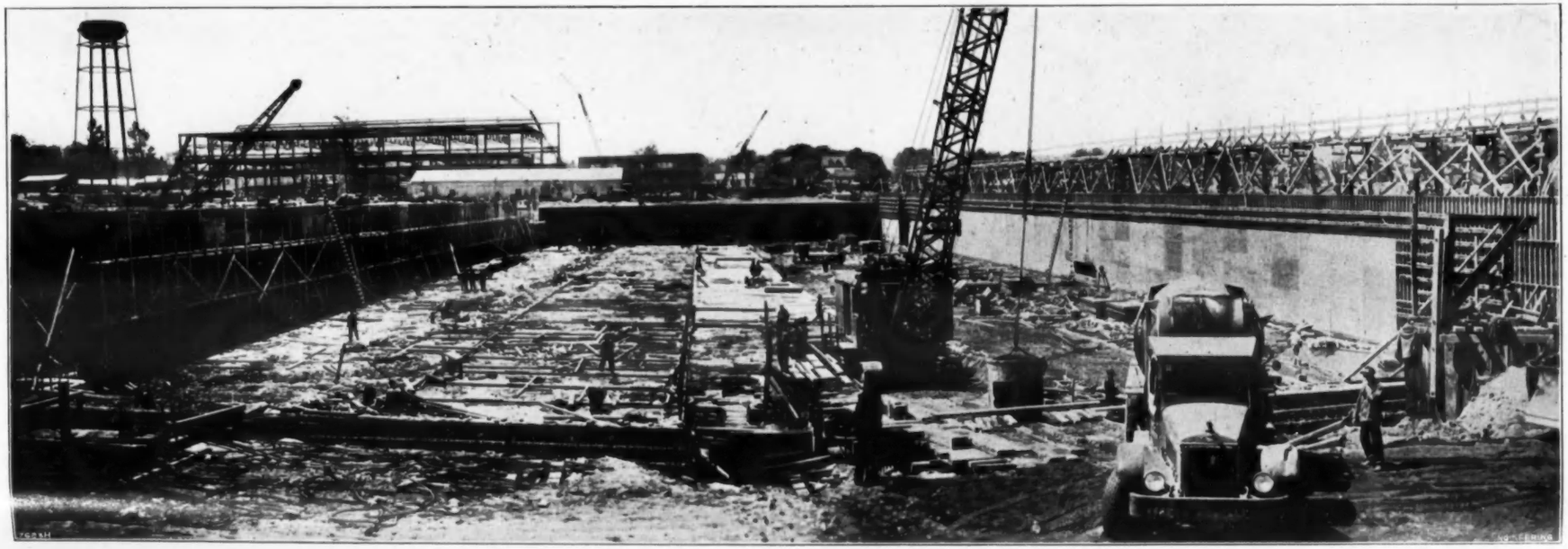


Fig. 8. Basin No. 2 under Construction. Berth No. 3 to Right, Berth No. 4 to Left.

WELDED TANK SECTIONS FOR 10,000-TON SHIPS.

TODD-CALIFORNIA SHIPBUILDING CORPORATION, RICHMOND, CALIFORNIA, U.S.A.

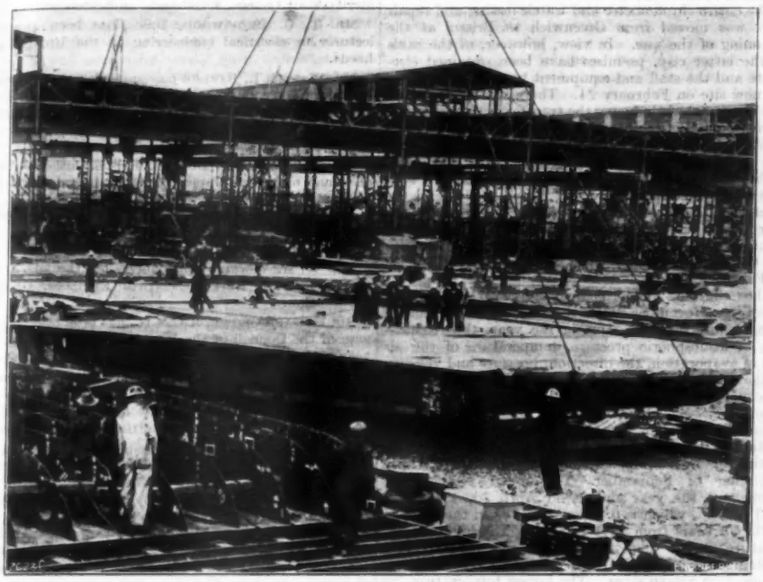


FIG. 3. LIFTING TANK SECTION FOR TRANSFERRING TO BERTH.

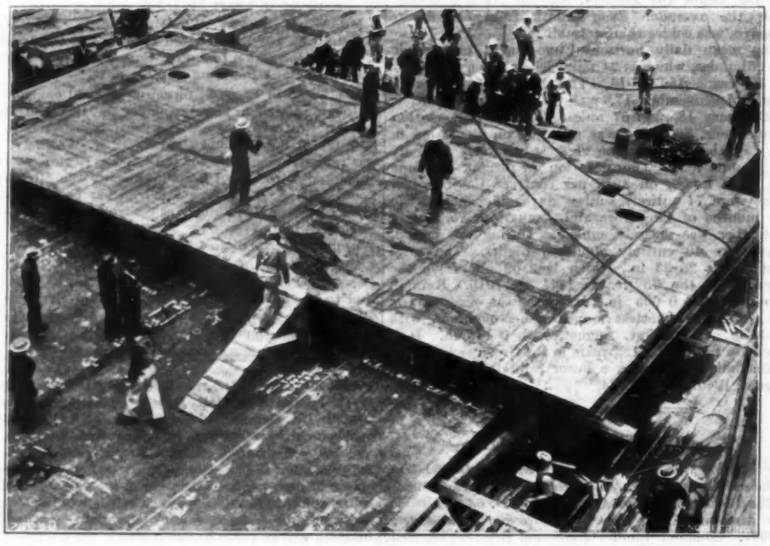


FIG. 4. TANK SECTION PLACED ON BOTTOM PLATING.

three-louvred building at the head of the berths is the plate shop. A little farther back and to the left of the plate shop is the mould loft and template store, with a welding-oxygen store and a first-aid post in front of it. The main offices, with canteen and parking ground, are still farther in the background and roughly in line with the mould loft. On the right bank of the waterway at the left of Fig. 5, which is known as the Lauritzen Canal, is another group of buildings. In the foreground a fitting shop is being erected and behind this will be the paint shop. Farther back is a large general stores, a pipe shop, a machine shop, distinguished by its clerestory roof, and a smithy. The main electric sub-station is situated at the right of the plate shop. The waterway at this side of the yard is known as the Parr Canal and is used as a timber pond, wharf site, etc., launching of the ships taking place in the deep water of the Santa Fe channel in the foreground. The available site for the yard is some 110 acres, and it is stated that, when work is in full swing, employment will be found for about 7,500 men.

The first stages in the construction of the vessels at Richmond are illustrated in Figs. 1 to 4. Welding is largely employed in this work, and in Fig. 1 is shown, lying upside down, the first tank section to be completed. This is the position in which the section is fabricated on the assembly platform of the berth concerned. The section is seen in Fig. 2 being turned over on the assembly platform, the view showing the underside. In Fig. 3, it is seen slung, preparatory to being lifted on to the previously-fabricated bottom plating, an operation which has been carried out in Fig. 4. That the section is wider than the bottom plating is accounted for by the fact that only the flat plating is in position, the curved bilge plating being added subsequently. The bottom plating is supported on chocks and keel blocks as on an ordinary slipway. Fig. 5 also shows, in Berth No. 3, one tank section in place on the bottom plating.

The type of ship to be built was decided by the Ministry of War Transport and the drawings were forwarded to the United States, where Messrs. Gibbs and Cox, naval architects, have collaborated in adapting the design to American shipbuilding conditions. According to the *Bulletin* of the American Bureau of Shipping, the principal dimensions are :—length, 416 ft.; breadth, 56 ft. 10¼ in.; and depth, to shelter deck, 37 ft. 4 in. The same authority gives the gross tonnage as 6,800 tons. The deadweight carrying capacity, as stated above, will be about 10,000 tons. The propelling machinery will consist of reciprocating engines taking steam from Scotch boilers fitted with superheaters.

The layout of the new shipyard at South Portland is shown in the plan, Fig. 6, on page 90. The South Portland yard, like the Richmond yard, has seven berths, but a different type of layout is followed. Whereas the ships are built in the Richmond yard on slipways, they are constructed in the South Portland yard in basins, closed by cofferdams. There are three of these basins for the seven berths; Basin No. 1 and Basin No. 2 having each two berths, while Basin No. 3 has three berths. Each berth has a total length of 450 ft. and a width of 77 ft., and is separated from its neighbour by a platform 23 ft. wide having its top 15 ft. above datum level. These platforms carry the tracks for the travelling cranes, which, for serving both the berths and the fitting-out pier, have a lifting capacity of 25 tons at a radius of 50 ft. The fitting-out pier, indicated at *a* in Fig. 6, has a length of 1,000 ft. and a width of 80 ft., its Tee-head being 200 ft. long by 75 ft. wide. This pier lies on the western side of the yard, and on the eastern side is a breakwater *b*. The design of the yard is due, we understand, to Messrs. Charles T. Main, engineers, Boston, Massachusetts, and the preliminary plans were completed early in December, 1940. Construction was commenced in January, 1941, and by June the whole yard was so well advanced that it was possible to start shipbuilding operations on some of the berths.

Referring again to Fig. 6, it will be seen that the yard lies practically north and south. To the rear of the basins is an assembly area *c*, 723 ft. long by 210 ft. wide. This area is accessible to the berth travelling cranes and is also served by a locomotive crane. The plate shop *d*, adjacent to the assembly area, is 500 ft. long by 100 ft. wide and at the respective ends are the power-house and sub-station *e*, and the tinsmith's shop *f*. The plate storage space, indicated at *g*, has an area of 450 ft. by 85 ft. The machine shop, *h*, measures 225 ft. by 100 ft., and the adjoining pipe shop, *i*, is 200 ft. long by 50 ft. wide. The general store, indicated at *j*, has a length of 300 ft. and a width of 75 ft. Welding is also largely employed at South Portland in ship construction and the lay-out of the yard includes a welding school with oxygen and acetylene generating plant. It is stated that, at the beginning of June, some 300 trainees were already undergoing a course of welding instruction. A number have already passed through the school and are being employed on actual welding on the ships. The welding school is open for the full 24-hour day, and is now in process of enlargement to accommodate a larger number of trainees. Other buildings on the site include the main offices, *k*, the garage, *l*, and the gatehouse *m*. There is also a cafeteria. Water is supplied from the water tower, visible in several of the views. Between the cofferdams are three pump houses, indicated at *o*, containing the equipment for emptying and filling the building basins which are, virtually, dry docks having cofferdams instead of swinging gates.

The series of views reproduced in Figs. 7 to 11, Plate III, were taken at the end of May and show the South Portland yard in various stages of construction. In Fig. 7, the structure of the water tower is seen on the extreme left. Beside this structure will be seen the framework of the plate shop, while, on the right of the figure, preparations are being made for Basin No. 3 and for the assembly yard at the head of the basins, this latter being in the centre of the figure. Fig. 8 shows Basin No. 2, looking towards the assembly yard, with the water tower, plate-shop framing and power house in the background on the left. This basin contains Berths No. 3 and No. 4, the divisions between the two berths being indicated by the concrete base seen running down the centre of the figure, which carries the crane track separating the berths. The method of construction of the walls can be made out on the right of the figure, a facing of concrete slabs forming the finish. In Fig. 9, work on Basin No. 3 is seen in progress. This view shows the site for Berths Nos. 5, 6 and 7, reading from right to left. The wall on the right is that between Basin No. 2 and Basin No. 3. Preparations for the concrete crane-track base between Berths Nos. 5 and 6 are in progress towards the right. The forms for the cofferdam base are seen in the foreground, also some of the concrete facing slabs. On the ground being excavated to the left will be erected the eastern wall of the whole group of basins.

The remaining figures on Plate III are both views of Basin No. 1. The basin is obviously not finished, but work on ship fabrication has been started in both the

berths contained in this basin. The berth seen in Fig. 10 is Berth No. 2. To the right will be seen the crane track which divides the basin into the two berths. This is not yet completed, but is sufficiently far advanced to enable the general lines of its structure to be followed. The same platform is seen on the left in Fig. 11; which is a view of Berth No. 1, the wall on the right of this figure being the western wall of the group of basins. It is formed of interlocking steel piling and has a solid fill on the outside. The shipbuilding operation seen in progress in the centre of this figure would appear to be that of setting the bottom hull plates preparatory to welding, these plates being supported on chocked-up beams. The cofferdam foundation is much more recognisable in both Fig. 10 and Fig. 11 than in the other views. The ground in front of it will, of course, be cut and dredged away so that the completed ships can be floated out, after removal of the cofferdam, and towed to the fitting-out pier.

It may be mentioned that somewhat similar ships are being built for the United States Marine Commission, there being a new shipyard for this purpose, also situated at Richmond, while, not far from the South Portland yard is another yard belonging to Messrs. The Bath Iron Works Corporation.

THE WORK OF THE ROYAL OBSERVATORY.

IN view of its location, it was not to be expected that the Royal Observatory at Greenwich would have escaped some material damage during the last twelve months or so. This, however, has not prevented the continuation of the greater part of its work, although some series of regular observations have been interrupted. These include those made with the transit-circle instrument, which, apart from breaks due to adjustments and alterations, has been in continuous use since 1851. Work was suspended on September 12, 1940. Up to that time 650,000 transit observations had been made, these forming the most important extant contribution, from a single instrument, to fundamental positional astronomy. Work with the reversible transit circle was also discontinued on September 11.

In the course of the year ended April 30, 1941, photographs of the sun were obtained with the photoheliograph on 260 days. The decline of activity from the high maximum of 1937-38 was found to continue, the frequency of sunspots being some 25 per cent. less than in the previous twelve months, and about half those of the maximum year, 1937. In spite of the lessened activity, there was no scarcity of sunspots and some 21 groups reached, or exceeded, 500 millionths of the sun's hemisphere. This is the lower limit for naked-eye visibility of a sunspot in the central region of the disc. Three of the groups exceeded 1,000 millionths. The computed times of central meridian passage of spots with areas of 500 millionths, or greater, were notified, as soon as the spot appeared, to the Superintendent of the Radio Research Station of the National Physical Laboratory; the Controller (Engineering) of the British Broadcasting Corporation; and the Engineer-in-Chief of Cables and Wireless, Limited. Six of the 21 large groups were associated with magnetic storms within four days of central meridian passage. The most active spot, as deduced from the number of radio fade-outs, was that of March 1, 1941.

The conditions prevailing during the year under review have necessitated a number of changes in the time service. The determination of time and the distribution of time signals were continued at Greenwich until September, 1940. The work was then transferred to Emergency Station A, the equipment of which had been proceeding during the previous twelve months. For some weeks observations were made at this station, the signals continuing to be sent out from Greenwich, but transmission from the latter was finally terminated towards the end of November. As equipment was not available at Emergency Station A to determine the relative personal equation of observers, and as certain new observers had to be introduced, the practice was introduced of employing observers in pairs until sufficient material to determine the relative personal equations was available. A second Emergency Station, B, has now been set up to ensure maintenance of the time service in the event of damage to Emergency Station A, or the Post Office lines used in the distribution of signals. Station B has been available for the emission of time signals since the end of December. It has taken over the Rugby rhythmic time signal during a number of periods. Two new short-wave receivers have been installed and a third is being purchased. Their performance has been highly satisfactory and it has been possible to secure more regular reception of American time signals. The records of the Nauen long-wave time signals have been supplemented by regular reception of the corresponding short-wave transmissions from D F C and D G Z. The long-wave American time signals from N S S and the long-wave signals from Bordeaux are also received. It is not known whether the Bureau de l'Heure continues to function, and corrections to Continental time signals have not been received.

The entire chronometer and watch testing and repair work was moved from Greenwich to Bristol at the beginning of the war. In view, however, of the raids on the latter city, premises have been obtained elsewhere and the staff and equipment were transferred to the new site on February 24. There was no interruption in normal work during the transfer, and in an audit carried out all instruments were accounted for. As an additional safeguard, reserve stocks of chronometers and watches have been widely dispersed. The work of the Nautical Almanac office has been interfered with by the destruction of type and plates by fire and the *Nautical Almanac* for 1942 was not published in the year under review. It was expected to appear this month. This date compares unfavourably with that for the previous year, when publication took place on February 28.

The routine meteorological observations, which began on November 9, 1840, have been continued without interruption. During the year, the registration of atmospheric pressure, temperature of the air and of evaporation, the direction, pressure and velocity of the wind, the amount of rainfall, of sunshine, and of cloudiness at night have been maintained continuously. Measurement of the solid matter in air by means of an Owens automatic filter has also been continued, but the measurement of gaseous pollution of the air by sulphur dioxide was given up at the beginning of September. The mean temperature throughout the year ending on April 30, 1941, was 49·3 deg. F., which is 0·2 deg. lower than the average of the 75 years from 1841 to 1915. The highest temperature in the shade, 85·7 deg., was registered on September 4. Temperatures exceeding 80 deg. were recorded on eleven days. The lowest temperature, on January 16, was 18·4 deg. Temperatures below freezing point were registered on 59 days. The mean temperature for the month of January, 1941, was 4·5 deg. below the average, and for April 2·9 deg. below the average. Each month from December, inclusive, was colder than normal.

The mean daily horizontal movement of the air was 261 miles, which is 24 miles below the average for the 50 years, 1867–1916. The greatest daily movement, on November 17, was 649 miles; the least, on February 18, was 57 miles. The greatest motion in one hour, 36 miles, was recorded on December 6, this day also showing the greatest pressure, 17·5 lb. per square foot. The duration of bright sunshine was 1,454 hours, on 32·5 per cent. of the possible. There were 74 entirely sunless days, 35 being in the two months of December and January. No day in September was entirely sunless. During the period, there were 40 entirely cloudless nights. The total rainfall was 26·33 in., which is 2·09 in. above the average for the 75 years, 1841 to 1915. Rainfall amounting to 0·005 in. or more was recorded on 148 days. The wettest month was November, with 6·864 in.; the driest, August, with 0·145 in. It is necessary to go back 122 years in the Greenwich records to find an August with a lower rainfall than that of August, 1940.

BOOKS RECEIVED.

The Birmingham Exchange. Directory of Members, Subscribers and Representatives, 1941. Birmingham: The Birmingham Exchange. [Price 2s. 6d.]

The Mercantile Year Book and Directory of Exporters, 1941. London: Lindley-Jones and Brother, Limited, 52, Bishopsgate, E.C.2. [Price 20s. net.]

Modern Assembly Processes. Their Development and Control. By J. L. MILLER. London: Chapman and Hall, Limited. [Price 13s. 6d. net.]

Mercerising. By J. T. MARSH. London: Chapman and Hall, Limited. [Price 32s. net.]

Workshop Ways. A Trainee's Introduction to General Workshop Practice. By A. C. KELSALL and A. E. MORGAN. London: Edward Arnold and Company. [Price 1s. 6d. net.]

United States National Bureau of Standards. Circular No. C 428. *A Test of Lens Resolution for the Photographer.* By I. C. GARDNER. Washington: Superintendent of Documents. [Price 40 cents.]

United States Bureau of Mines. Bulletin No. 433. *Open-Cut Metal Mining.* By E. D. GARDNER and MCHENRY MOSIER. [Price 40 cents.] Bulletin No. 435. *Metal-Mine Accidents in the United States During the Calendar Year* 1938. By W. W. ADAMS and MARY E. KOLHOS. [Price 10 cents.] Washington: Superintendent of Documents.

The Hokkaido Imperial University Calendar, 1940-1941. Sapporo, Japan: The Librarian, Hokkaido Imperial University.

PERSONAL.

MR. E. O. TAYLOR, B.Sc., A.C.G.I., A.M.I.E.E., lecturer in electrical engineering at the City and Guilds Engineering College, South Kensington, is taking up the position of senior lecturer in electrical engineering at the Heriot-Watt College, Edinburgh, on September 1.

MR. T. G. BRIDGWOOD, B.Sc., has been appointed lecturer in electrical engineering at the University of Leeds.

MR. WALTER L. BARBER has succeeded the late SIR C. HERBERT SMITH as chairman of the Midland Electric Manufacturing Company, Limited, Tyseley, Birmingham, 11. He will continue to act as managing director. MR. E. WITHINGTON has been made deputy chairman.

SIR BERNARD D. F. DOCKER, K.B.E., hitherto deputy chairman of Messrs. James Booth and Company (1915), Limited, Argyle-street, Nechells, Birmingham, 7, has been elected chairman in succession to the late SIR C. HERBERT SMITH. SIR PATRICK HANNON has been elected a director of the Company.

MR. W. A. WOODROW has succeeded the late MR. D. MCDOUGALL as Burgh Electrical Engineer, Greenock Corporation.

SIR EDWARD CROWE, K.C.M.G., has been elected chairman of the Council of the Royal Society of Arts for the year 1941-42.

MR. F. H. KEENLYSIDE has been appointed private secretary to Lord Leathers, Minister of War Transport.

MR. D. M. EVANS BEVAN has been elected a director of the London Midland and Scottish Railway Company.

MR. S. J. HUNGERFORD, president of the Canadian National Railways, has relinquished this position while retaining that of chairman of the board. He has been succeeded in the presidency by MR. R. C. VAUGHAN, formerly vice-president. Mr. Hungerford has also resigned from the presidency of Trans-Canada Air Lines in which he has been succeeded by MR. H. J. SYMINGTON.

MESSRS. EMMOTT AND COMPANY, LIMITED, inform us that the editorial, advertising and publishing offices of *The Textile Manufacturer*, *The Mechanical World*, *Mechanical World Year Book* and *Electrical Year Book* have now been moved to 78, Palatine-road, Manchester, 20 (Telephone Didsbury 3204–5).

MR. W. M. SELVEY, Wh.Sc., A.R.C.Sc., M.Inst.C.E., M.I.Mech.E., has been elected President of the Institute of Fuel in succession to LIEUT.-COL. SIR JOHN GREENLY, K.C.M.G., C.B.E., as from October next.

MR. T. MUIR WILSON, formerly regional controller of factory and storage premises under the Board of Trade, for the Northern Region, has been transferred to the Ministry of Supply, and CAPTAIN S. N. WHIBLEY, who was regional controller for the Eastern Region, has been appointed Director of Warehousing at the Ministry of Food. MR. S. A. SADLER FORSTER has been appointed to succeed Captain Whibley as controller for the Eastern Region, while VISCOUNT TEMPLETOWN succeeds Mr. Wilson in the Northern Region.

The Minister of Works has appointed MR. T. P. BENNETT, F.R.I.B.A., to be Director of Works, in succession to the late COLONEL C. L. HOWARD HUMPHREYS. Mr. Bennett was formerly Director of Bricks and afterwards became Deputy Director of Works.

THE MELCHETT MEDAL.—The Council of the Institute of Fuel have decided to award the Melchett Medal for 1941 to Dr. Clarence A. Seyler, D.Sc., F.I.C., F.Inst.F., of Swansea, in recognition of the research work, on coal and its constitution, which he has carried out and published for the benefit of the world at large over a period of many years. It is hoped to present the Medal to Dr. Seyler in October, when he will deliver the Melchett Lecture, and a further announcement regarding this function will be made in due course.

THE BIRMINGHAM EXCHANGE.—The 1941 edition of the Directory of members, subscribers and representatives of the Birmingham Exchange has recently been published. In addition to an alphabetical list of members and subscribers of the Exchange and of their addresses and telephone numbers, the little volume contains an alphabetical classification of professions and trades, a brief history of the foundation of the Exchange, a list of its by-laws, and other sections of interest to members. Copies, price 2s. 6d., are obtainable from the Secretary, The Birmingham Exchange, Birmingham.

SANITARY INSPECTORS' EXAMINATION.—For the duration of the war, candidates who have served in the hygiene sections of the Royal Army Medical Corps will be allowed by the Royal Sanitary Institute and Sanitary Inspectors' Examination Joint Board to qualify under Regulation 4, by producing a certificate of having worked 125 days in a public-health department, spread over a period of not less than six months, and of having received instruction during that time, in all branches of the work and duties of a sanitary inspector, or not less than 150 working hours.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Many Sheffield works are closed down this week, and will resume operations on Tuesday next. The large steel-producing concerns will be on holiday during August Bank Holiday week; after that the local industries will work continuously until Christmas. There is a heavy demand for all types of steel products, and producing works have well-filled order books. The call for raw and semi-finished materials has been well maintained, and deliveries to customers are highly satisfactory. A heavy run has developed in steelmaking alloys. Among the steels in demand are heat- and acid-resisting types, and materials capable of withstanding heavy strain and wear. Though the heavy machinery and engineering branches are busily employed on Government orders, a fair amount of ordinary commercial business is still being done. There is a brisk call for steelworks' and ironworks' machinery and ancillary equipment. Shipbuilding steel, turbine parts, boiler drums, and deck furnishings are all in strong request. Mining plant is a progressive line; coal-cutting machinery is being used more extensively, and a larger tonnage of steel props and girders is being used underground as compared with a year ago. Steel tubs and winding gear are in demand, and wire-rope makers are exceptionally busy. The market in electrical plant has increased considerably, and Sheffield works are supplying a variety of products, including steel, for the manufacture of generators, transformers, and switchgear. Agricultural steel machinery and parts, and implements form an active section; the demand for harvesting plant has exceeding expectations. Rising outputs are reported by the toolmaking branches. Engineers' small tools are in strong demand.

South Yorkshire Coal Trade.—The export position shows little change. The inland market is steady, outputs tending to improve at many collieries in this area. There is a heavy demand for industrial and locomotive coal, and smalls and slacks are in demand for power stations. Gas coke is steady, and foundry and furnace coke are active media. The house coal market is more buoyant.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Further increases have been announced in the prices of all Welsh coals. These, as authorised by the Secretary for Mines, were 10*d.* per ton, in the case of bituminous and dry steam descriptions, and 1*s.* 8*d.* per ton, in the case of anthracite fuels. It was explained that this increase, which applies to all deliveries made since July 19 and is also applicable to all existing contract supplies and unexecuted orders, has been made necessary by the recent increases in miners' pay and also by the levy on production entailed in the guaranteed week introduced under the Essential Work Order. Similar increases, it was understood, will be introduced into all the other coalfields, but it was reported that South Wales was the first district to bring them into operation. Pending the signing of a new agreement, the South Wales Joint Production Committee decided that the present arrangements for payment in respect of Sunday production shifts, which were reached in June of last year, should continue in operation. It will be remembered that the miners, as a result of a ballot taken through the lodges, recently refused to accept the terms for the payment of the shift recommended by their executive Council. The steam-coal market was still firm. A good volume of business was available on both home and foreign account. Supplies of practically all descriptions, however, were difficult to arrange for, especially for early delivery. Inland customers were anxious to make heavy purchases for stocking purposes, in addition to those required for industrial use. On export account there was again a good demand from buyers in South America and Portugal. Best large coals continued to move off satisfactorily and the sized kinds were only sparingly available for early delivery. There was a keen request for the bituminous small classes which were almost completely disposed of for some time to come and were strong. Dry steam smalls, on the other hand, were freely available to meet a slow request and were dull. Cokes remained busy and patent fuel quiet.

The Iron and Steel Trade.—Activities were well maintained in the iron and steel and allied trades of South Wales and Monmouthshire last week. The demand for most products was steadily maintained and the works still held well-filled order books and were engaged almost to full capacity.

SOUTHERN RHODESIA MINERAL PRODUCTION.—The value of the mineral production of Southern Rhodesia for the first six months of the present year is 4,499,000*l.*, which total is just above that for the corresponding period of 1940.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—A tendency to reduce the volume of new business in certain commodities is a temporary phase of the market which is not unusual at this season of the year and is attributable to the prospect of a partial suspension of operations at the works for the customary August holidays. The consequence is the easing of the position in regard to deliveries. At the same time the aggregate tonnage output of iron and steel must be maintained for war purposes. This is emphasised by a new Control Order to enforce the distribution regulations.

Cleveland Iron Trade.—Foundry owners are experiencing no difficulty in obtaining ample supplies of pig for their requirements notwithstanding the continued scarcity of Cleveland qualities and are actually adding slightly to their moderate stocks. Exceptionally extensive use of scrap is still being made. Deliveries of Midland pig continue at a satisfactory level and are used for most purposes in this area. Particular qualities of iron required for certain specified uses are obtainable in adequate parcels from other producing centres. Recognised market values of Cleveland pig are at the equivalent of No. 3 description at 128*s.* delivered in the Tees-side zone.

Basic Iron.—The nominal price of basic iron remains at 120*s.* 6*d.* While the heavy output fully meets the demands of the makers' own steelworks, it leaves no saleable tonnage.

Hematite.—Conditions in the hematite branch of trade are more satisfactory than has been the case recently. The demand continues considerably in excess of supply, but is diminishing as the use of substitute iron extends. The stringency is eased to some extent by occasional imports of overseas products made from hematite. The rationing of consumers, however, is still unavoidable. Official quotations are ruled by No. 1 grade of iron at 138*s.* 6*d.* delivered to North of England buyers.

Foreign Ore.—Most kinds of foreign ore are coming to hand in quantities that suffice for current needs, but the descriptions needed for the manufacture of hematite are somewhat difficult to obtain.

Blast-Furnace Coke.—Sellers of Durham blast-furnace coke have a large tonnage for disposal but are not anxious to transact extensive business until they have reduced their obligations under running contracts and, as local users are extensively covered, the market is quiet.

Manufactured Iron and Steel.—The imports of semi-finished iron and steel have been reduced in order to free the shipping space for other uses, but stocks are substantial and deliveries of local products are large so that satisfactory supplies to the re-rolling mills are ensured. In most of the finished industries, the tonnage output is heavy, but the production of sheets has been reduced and manufacturers of joists and sections could handle more work. Ship, tank and boiler plates are in brisk demand and all available parcels of special alloy steels are readily taken up; railway material is in good request.

Scrap.—Maximum deliveries of heavy and mixed iron and steel scrap are still required, but the demand for other descriptions of material is less urgent.

AMERICAN SOCIETY FOR TESTING MATERIALS.—The Charles B. Dudley Medal for 1941 was presented to Professor C. W. MacGregor, of the Massachusetts Institute of Technology, at the annual meeting of the American Society for Testing Materials, held recently in Chicago. The award was in respect of Professor MacGregor's paper, "The Tension Test," presented at the 1940 annual meeting of the Society.

FUEL LUNCHEON CLUB.—At a meeting of the Committee of the Fuel Luncheon Club, Sir David Milne-Watson, Bart., LL.D., F.Inst.F., was nominated President of the Club for the coming session. He is to succeed Lt.-Col. W. A. Bristow, M.I.E.E., F.Inst.F., who has occupied the chair for the past two years. It is anticipated that Sir David will commence his year of office at the first meeting of the Club in October next, the date of which will be announced in due course.

ROAD-HAULAGE (OPERATIONS) ADVISORY COMMITTEE.—The Minister of War Transport has set up a Road Haulage (Operations) Advisory Committee to advise him on the operation and development of the Government road-haulage scheme. The Chairman is Major G. A. Renwick and the members comprise Messrs. I. Barrie, W. J. Elliott, C. Holdsworth, J. S. Nicholl, C.B.E., G. Smart, M.B.E., R. W. Sewill, and J. H. Turner, O.B.E. Mr. A. H. Lomas of the Ministry of War Transport, Berkeley Square House, Berkeley-square, London, W.1, has been appointed secretary.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—During the holiday stoppage last week some extensive plant repairs were carried out. The re-start was reported as quite satisfactory and production is now in full swing. The demand for steel is strong but the supply is ample for all Government contracts as licences for material for purposes which are not considered to be of an essential nature at the present time are not being granted. The result of this policy is that delays in deliveries against specifications have been reduced to a minimum. Ship plates, boiler plates, and sectional material are all in steady demand and the consumption of high-grade steel for special purposes is expanding. Although black and galvanised sheets are a little quieter, the works are busily occupied in fulfilling contracts now on the books. Prices are unchanged and are as follows:—Boiler plates, 17*l.* 12*s.* 6*d.* per ton; ship plates, 16*l.* 3*s.* per ton; sections, 15*l.* 8*s.* per ton; medium plates, ¼ in. and thicker, rolled in sheet mills, 21*l.* 15*s.* per ton; black-steel sheets, No. 24 gauge, 22*l.* 15*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, 26*l.* 2*s.* 6*d.* per ton, all for home delivery.

Malleable-Iron Trade.—Production re-commenced at the malleable-iron works in the West of Scotland this week and as order books are fairly well filled a steady run is assured. Specifications from the rivet, bolt and nut makers have been very satisfactory and the demand is likely to continue. The position of the re-rollers of steel bars has changed but little and makers are still able to undertake near-date delivery for new business as they are well placed for raw material. The following are the current quotations:—Crown bars, 15*l.* 12*s.* 6*d.* per ton; No. 3 bars, 13*l.* 12*s.* 6*d.* per ton; No. 4 bars, 13*l.* 17*s.* 6*d.* per ton; and re-rolled steel bars, 17*l.* 15*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—Activity continues in the Scottish pig-iron trade and, as the furnaces have been kept in full blast without interruption, some stocks have been accumulated which will materially assist consumers—especially of hematite iron. The demand for foundry grades is still slow. Prices are unchanged and are as follows:—Hematite, 6*l.* 18*s.* 6*d.* per ton, and basic iron, 6*l.* 0*s.* 6*d.* per ton, both delivered at the steel works; foundry iron, No. 1, 6*l.* 5*s.* 6*d.* per ton, and No. 3, 6*l.* 3*s.* per ton, both on trucks at makers' yards.

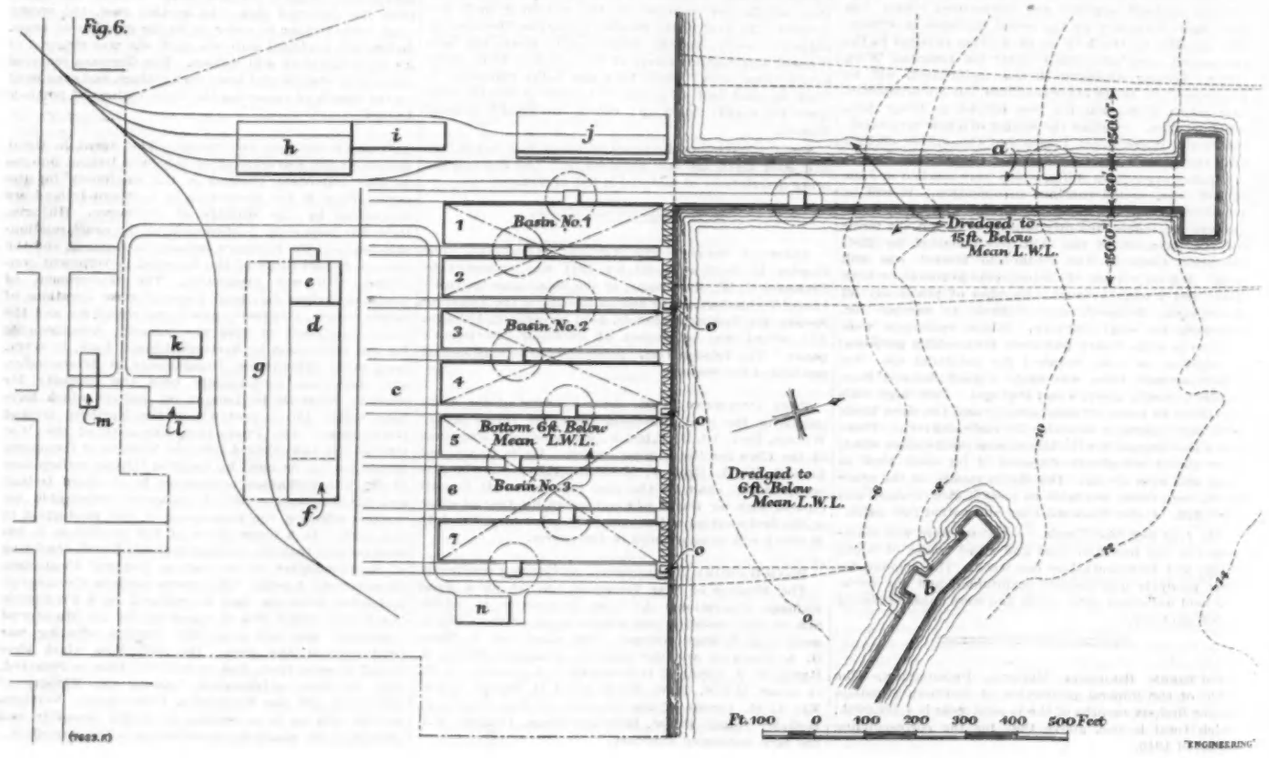
SHORTAGE OF BRASS IN GERMANY.—Evidence that Germany is suffering from a shortage of certain metals and alloys, in particular, brass, is indicated by the way in which German raiders have treated a few ships which they have captured. In one case, apart from provisions and ordinary stores, engine packing and brass were particularly sought out and taken over to the raider from the captured ship. In another case, the enemy went even further in order to secure supplies of brass. Before the captured ship was sunk she was stripped of all her brass work and fittings. The Germans removed all cooking utensils and brass deck fittings, and even went to the length of removing the brass casings of porthole frames.

WAR PRODUCTION IN ULSTER.—The Agent in Great Britain of the Government of Northern Ireland informs us that important changes in the machinery for the organisation of war production in Northern Ireland are announced by the Ministry of Commerce. Hitherto, there has been some confusion as to the exact relationship between the Northern Ireland Government and the various Departments of the Imperial Government concerned with war production. The Government of Northern Ireland has been responsible for questions of labour supply, transport, power and electricity and the whole machinery of civil government. Arrangements for war production in Northern Ireland have, however, been made directly by Departments at Westminster, and there has consequently been the necessity for constant reference to London on matters which have been within the competence of the Northern Ireland Government. The Production Executive of the War Cabinet has now decided that the Ministry of Commerce should become its agent for ensuring the due performance of the war-production programme in Northern Ireland and should become the Department responsible for matters affecting the programme of war production in this area. As a consequence of this resolution, it has been decided that the existing Regional Board, consisting of representatives of the various Imperial Production Departments, together with representatives of employers and trade unionists, shall be replaced by a Production Committee, which will be appointed by the Minister of Commerce and will deal with matters affecting war production in this area. The difficulties which were bound to arise from dual control will thus be removed, and, by close collaboration between the Ministry of Commerce and the Production Departments, Northern Ireland will be in a position to make, smoothly and efficiently, its maximum contribution to the war effort.

TODD SHIPBUILDING YARDS IN THE UNITED STATES.

(*For Description, see Page 86.*)

FIG. 5. AERIAL VIEW OF SHIPYARD AT RICHMOND, CALIFORNIA, UNITED STATES.



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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

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TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

INDEX TO VOL. 151.

The Index to Vol. 151 of ENGINEERING (January-June, 1941) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, no copies of the Index are being distributed, except in response to such applications.

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One Two-Page Plate.—THE TODD-BATH IRON SHIPBUILDING CORPORATION SHIPYARD, SOUTH PORTLAND, MAINE, U.S.A.

ENGINEERING

FRIDAY, AUGUST 1, 1941.

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WAR AND THE INVENTOR.

EXCEPT to those who have come into direct contact with it, a certain air of mystery has shrouded, hitherto, the work of the various scientific research organisations associated with the war departments of the Government. Apart from brief announcements that Directors of Scientific Research had been appointed by the Admiralty, the Ministry of Supply and the Air Ministry, the general public was afforded little inkling of the efforts that were being made to co-ordinate the vast reserves of inventive talent in the country; and, to judge by the inquiries that have been received in this office from time to time, the very existence of these officers was unsuspected by many who desired to bring suggestions to the notice of the appropriate authorities. If, in this respect, there have been shortcomings in the official publicity arrangements in the past, however, it must be conceded that the arrears have been handsomely overtaken by the address by Dr. H. J. Gough, F.R.S., Director of Scientific Research, Ministry of Supply, which is reprinted on page 94 of this issue of ENGINEERING. When it is considered that the number of inventions and proposals submitted during 1940 was not far short of twice the aggregate of the preceding five years' totals, and that the total from the outbreak of the war to the end of June, 1941, amounted to 50,534, some idea may be gained, both of the magnitude of the task, and of the complexity and quality of the organisation needed to cope with such a spate of ingenuity.

To appreciate to the full what is involved and what has been accomplished in creating such a world-wide co-operation of technical and scientific talent, it is necessary to bring to the reading of Dr. Gough's address something of the imagination and breadth of vision that went to its inception. In a sense, it may be said to have grown out of that small nucleus, less than 40 all told, who constituted the civilian research and experimental staff of the War Department at the outbreak of the previous war in 1914. The succession is legitimate enough, no doubt, between that small band of 1914 and the 2,700 skilled staff who are directly employed to-day by the Ministry; but the means and methods of warfare, by land, sea and air, have altered so greatly in the past quarter of a century that it may be questioned whether, to continue the metaphor, it has not proceeded by special remainder at some intermediate stage. What has taken place is virtually the creation of a new department; and, remembering all the accusations of short-sightedness that have been levelled against the various representative heads of war departments from time to time, there is a peculiar satisfaction in realising how extensive were the arrangements already in existence before the war broke out in 1939. Foresight is by no means the German monopoly that some would make it out to be; and there is some evidence in Dr. Gough's survey, general though it necessarily is, that the claim that "muddling through" is the most characteristic feature of this country's talents is as superlative a piece of under-statement as has yet been achieved in this peculiarly British form of rhetoric. At all events, those who regard "planning" as a sort of universal panacea in human affairs are now provided with an excellent example of its successful application in practice.

The difficulty of organising so extensive a system of collection, examination and ultimate possible development of ideas must have been greatly enhanced by the impossibility of predicting the directions which future invention might take or the proportion which might be expected to yield fruitful results. Actually, we understand, the serviceable proposals have proved to be no more than about one in 400 of those submitted; a small proportion, it may seem, yet one alone out of the total of 50,534 would fully justify the creation and maintenance of the Directorate of Scientific Research if that one could ensure a victorious termination of the war. But if no more than one workable proposal should emerge from fifty thousand, it would still be necessary to examine them all with equal care; just as, in reading proofs of printed matter, every word must be examined for possible errors, even though no error may be found. It is obvious, therefore, that a great part of the time and money spent by the Directorate is inevitably unprofitable, though it cannot be said to be wasted. On the other hand, much of this unprofitable time might be saved if inventors and proposers, not technically skilled themselves, could be persuaded to make more use of the advice of their better-equipped friends, or, in the case of members of institutions, to communicate in the first place with the inventions committees which a number of these bodies have set up for the purpose of assisting inquirers to bring their schemes to the notice of the proper authorities.

It is no part of the terms of reference of such committees to sit in judgment on the proposals which come before them, though they might (and, doubtless, do) point out to the author of a proposal or invention any fundamental transgression of physical law, likely to invalidate his scheme at the outset. Indeed, it may well be that some notion, untenable in itself for reasons that its begetter is unable to appreciate, contains the germ of a suggestion for the solution of some totally different problem that is simultaneously occupying the attention of the Ministry's examiner. In a somewhat different category, however, are the relatively numerous suggestions which have been received by the Ministry for filling anti-aircraft shells with tar or some similar substance, with the object of covering the enemy pilot's windscreen and so blinding him; the proposers having missed the seemingly obvious point that a shell which bursts so close to the target would be much more effective if it contained high explosive.

Such suggestions as this, the proposers of which are probably deeply in earnest in their desire to assist the prosecution of the war, may be more difficult to dispose of than the many submissions which are merely fantastic, sometimes to the point of sheer absurdity; for example, schemes for spreading bird-lime on enemy aerodromes, using sea lions to clear enemy minefields, or setting up artificial North and South Poles in the East and West of England to upset the compasses of enemy aircraft. There was, perhaps, the inspiration of Biblical precedent behind the notion of wrapping incendiary "leaves" round the bodies of rats, which were then to be released among enemy docks and storehouses; though it does not appear that the sponsor of this idea had considered how the

preliminary task of fitting the rats with their combustible cummerbunds was to be accomplished.

One of the most satisfactory features that emerges from Dr. Gough's illuminating address is its assurance of the care that is taken to ensure that no submission is rejected out of hand merely because, as submitted, it is not obviously practicable or superior to existing equipment. Apart from the routine procedure of circulating particulars to all departments likely to be interested, in case a device which is of no use to one Service may be of value to another, the freedom accorded to the examiners to reconsider rejected proposals, and to suggest their own modifications in the light of knowledge that an inventor cannot be expected to possess, has resulted in the introduction of various devices and improvements on existing equipment. An instance is a certain type of light smooth-bore ordnance which was originally rejected on the ground that better weapons were already in use. On re-examination, however, it was realised that the proposed weapon could be produced in large numbers more rapidly than the existing type, and without diverting production capacity from the better weapons. For these reasons, the examiner strongly pressed for further consideration of the proposal, with the result that some thousands of pieces, with their ammunition, are now becoming available, representing a definite increase in the national armaments and not merely a substitution of one type for another. In another case, a design for a light grenade-thrower was submitted and initially rejected. The proposal possessed sufficient merit, however, to justify actual trial, which was carried out in the presence of the examiner (who had himself suggested a modification to overcome one stated objection to the design) and of Service representatives. The weapon proved to be quite a useful type of its kind, but was eventually rejected on the ground that another design, similar in purpose, was already in production. Even so, Dr. Gough pointed out, the rejection is not absolute; if the quantity of the existing weapon, now on order, proves to be insufficient, the matter will be reconsidered yet again.

These examples should reassure any inventors who may still fear that their laboriously-prepared schemes are liable to be cast into the outer darkness solely on the *ipse dixit* of some self-sufficient and self-satisfied brigadier of the type beloved of the popular cartoonist. In fact, as Dr. Gough repeatedly emphasised, the greatest care is taken to guard against any such danger. There are certain additional points, however, which might be mentioned here for the benefit of possible inquirers. One of the most important, perhaps, is that the communication of inventions and suggestions to the Ministry of Supply is confidential, and does not constitute publication, under the Patents Acts; nor are the inventor's interests prejudiced thereby if he should, at any time, desire to apply for Letters Patent. It is entirely at the discretion of the inventor, therefore, whether to file his application at the Patent Office before submission or subsequently, or not at all. This point is stated very definitely in the *Memorandum for Inventors*, No. 35A, compiled by the Ministry, copies of which are obtainable from the Secretary, Ministry of Supply, Adelphi House, London, W.C.2.

Past experience shows that any national emergency causes an immediate increase in the flow of suggestions. This fact is well brought out in the graph reproduced on page 95 of this issue; each of the peaks shown therein is related to some outstanding event in the progress of the war, when the danger to the country has appeared more than usually critical. It is not to be expected that the last of these crises has been experienced yet—as the Prime Minister warned the House of Commons and the nation at the conclusion of his speech on production, on July 29; so that there is every prospect that the organisation of the Directorate of Scientific Research has other overloads in store, comparable with that which followed the German sweep to the Channel coast and the collapse of France. It is to be hoped, therefore, that Dr. Gough's address may have a timely effect, both in reducing the flow of inherently unpracticable suggestions and in encouraging the submission of others, more practical in character.

WEIGHTS AND MEASURES.

IT is customary in this country for a draughtsman to dimension his drawings in feet and inches; in the United States he may use inches only, even in civil engineering work in which measurements may run up to thousands of these units. Common British practice, however, is based on the foot, and the shop operative would be surprised, and possibly confused, if he were told that the height of centres of a faceplate lathe was three-quarters of a yard; he would think of it as 2 ft. 3 in. or 27 in. His wife, on the other hand, buying material at the draper's, will ask for three-quarters of a yard as a matter of course, and would be equally confused in her turn if she were told that what she wanted was 2 ft. 3 in. The reason why the engineering trades are based on the foot, and the textile trades on the yard, is lost in the mists of the history of handicrafts. The foot may claim the greater antiquity, as it descends from Roman times, its division, the inch, being a corrupted form of the Latin *uncia*, meaning the twelfth part. The yard is Old English and originally had various lengths. It was officially determined by an Act of Parliament of 1878. The foot and yard have no historic connection, but it is not merely a practical convenience that one is a third of the other. They live together in amity because both, in common usage, are based on the inch.

With every respect to the metric system, it is probably correct to say that the most convenient method of subdividing a standard is by a process of continual halving. Most household commodities, for instance, are sold in pounds, half-pounds and quarter-pounds, although present-day circumstances have introduced the general public to a new familiarity with ounces. Jam is put up in 2-lb., 1-lb. and, in normal times, ½-lb. pots. The halving process is also widespread in the practical employment of the yard. It regulates, for instance, the width of textile materials. The standards 27 in. and 54 in. are respectively three-quarters of a yard, and a yard and a half. The common brick, also, is a quarter of a yard long, although it is not usually spoken of, or even thought of, in that way. It might appear that the stone, of 14 lb., another everyday measure, is a departure from the halving and doubling system, but its own multiples and fractions follow the same rule. It is half a quarter, which itself is a quarter of a hundredweight; and 7 lb., which in happier days fixed the size of a large pot of marmalade, is half a stone. The quarter-stone, too, is in general use in the North of England for the retail sale of various bulky commodities, such as potatoes and flour, and is recognised as such by the Ministry of Food in its announcements of price control. The 14-lb. unit is a survival from among commercial stones of varying dimensions. A writer in the *Times Educational Supplement*, in 1923, suggested that the 14 lb. value had survived owing to its direct relation to the seven days over which many weekly domestic purchases have to be spread.

In view of the widespread use of a system of division based on the series $\frac{1}{4} : \frac{1}{2} : 1 : 2$, it would appear that everyday convenience would be better served were it possible to use the system of notation based on 8 instead of 10. This is known as the octenary scale of notation, the system in common use being the denary scale. At times it has been suggested, particularly by critics of the metric system, that the duodenary notation, based on the number 12, would be the most convenient in practice, 12 being divisible by 2, 3, 4 and 6, while 10 is divisible only by 2 and 5. In octenary notation, the radix, 8, is also divisible by two numbers only, 2 and 4, but the practice of mankind suggests, none the less, that it is the most convenient in use. Had man developed with eight fingers, as birds have eight toes, we might have had the octenary system; as things are, neither that nor the duodenary notation is likely to come into use. It may be of some interest to note, however, that there is no practical difficulty in changing the system of notation for special purposes. As it happens to be convenient, the lengths of articles for these columns are calculated on the octenary system, following the $\frac{1}{4} : \frac{1}{2} : 1 : 2$ series. Thus an article described as being "0-5" long fills five-eighths of a column, not half a column, and one 0-6 long represents three-quarters of a column. There is no difficulty in operating this process, for its special purpose, in parallel with the denary notation for the other affairs of life.

It is not to be pretended that the halving and doubling system, so widely used, does anything to straighten out our complicated tables of weights and measures. Logically applied, it would lead to a ton of 2,048 lb. The simplification introduced in the United States by the introduction of the short ton of 2,000 lb. does not represent an approach to the continuous-doubling process. It is as wide of the mark as our 2,240 lb. The same remark applies to the United States gallon, which has historical, but apparently no tabular or arithmetical, justification. It represents 231 cub. in. Our gallon, of 277¼ cub. in., is at least equal to four quarts, or eight pints. As there is a completely worked-out alternative to our illogical system of weights and measures already in existence, it is not likely that the complicated tables of the arithmetic books, with their 5½ yards equalling one rod, pole or perch, will ever be recast on a rational basis. They have grown up, each for its own purpose, as practical working compilations and are likely to stand. Their disadvantages, however, are obvious; for instance, it is a definite inconvenience that there is no linear unit corresponding to a rood or an acre. An acre is 4,840 sq. yds. and the nearest approach to this with whole linear units is 4,900 sq. yds., which is the area of a square with 70 yd. sides. This approximation, however, is not near enough for practice, although some tolerance must always be allowed.

For scientific purposes, the metric system is firmly established, but there does not appear any immediate prospect that it will be adopted for everyday affairs either in Great Britain or the United States. The difficulty of bringing it into common use may be seen even in France, which introduced it in 1792 and made it obligatory in 1840, for those who do retail shopping in that country still find commodities sold by the livre and demi-livre. Whether or not any effort is ever made to make the use of the metric system compulsory in this country or the United States, it will continue as the only international system, so that its relation to other methods of computation is of importance. In a paper entitled "A Precision Value for the Inch," presented to the American Institute of Weights and Measures in 1928, Mr. L. D. Burlingame, of the Brown and Sharpe Manufacturing Company, pointed out that the United States equivalent of an inch was 25·40005 mm., the corresponding British figure being 25·39998 mm., this difference arising from the fact that an Act of Congress, in 1866, established the metre as having a length of 39·37 in. This was rather working backwards. The length of the metre, although it is not the forty-millionth part of the circumference of the earth at the equator, as its introducers thought it was, is none the less definitely fixed. To define it in terms of inches is to define the inch, not the metre. Incidentally, Low's *Pocket-Book for Mechanical Engineers* (1938 edition) gives the length of an inch as 2·5399541 cm.

These remote decimal places need not concern us at the moment, especially as the purpose of Mr. Burlingame's paper was to suggest the establishment of the length of the inch as 25·4 mm. He pointed out that the inch is probably the most important unit of length in manufacture in the world as a whole and that, by fixing this simple ratio, conversion for metric work would be easy. Incidentally, by the use of a gear ratio of 5 to 127, it would permit the cutting of metric threads on a lathe having a lead screw with a pitch in inches, and *vice versa*. The obvious British objection to the proposal is that it would scrap the standard yard on which all our linear measurements are based. At the Seventh International Conference on Weights and Measures, held in 1927, it was agreed to recommend that the length of the metre should be defined as equal to 1,553,164·13 wavelengths of red cadmium light. If a basis of this kind is generally accepted and is extended to the yard, slight modifications of accepted standards would present no scientific difficulties, although they might introduce practical ones, particularly when great lengths have to be dealt with.

In machine work, in which Mr. Burlingame was interested, an inch of 25·4 mm. is probably near enough, and this figure is frequently used by those who build machinery to the two systems of measurement. If any difference caused by a slight modification in the unit of length falls within the limits of tolerance of any particular article, then it may be ignored. This aspect of the matter was dealt with by Mr. H. W. Bearce in a paper presented at the Thirtieth National Conference on Weights and Measures, which was held at Washington in June, 1940. He pointed out that no standard is absolutely correct, and that the matter of interest was to determine how nearly correct a standard must be, adequately to perform the purpose for which it was intended. This consideration led to standards having various degrees of tolerance for different classes of work. A table of weights issued by the Bureau of Standards specified three degrees of tolerance, the degree adopted naturally depending on the class of work to which the standard was applied. Furthermore, the tolerances were not in proportion to the weights; the tolerance on a 2-lb. weight was not twice that on a 1-lb. weight.

This elementary information illustrates the impossibility of facilitating metric manufacture simply by specifying a 25·4-mm. inch. The departure from true millimetre length might fall within the allowable percentage error in machine-tool building, but when the new inch was multiplied many thousandfold, say, for land-survey work, the error would be cumulative. Certainly, it would usually be small, even then; taking the value of the British inch as given by Mr. Burlingame, the error in a mile would be 1·2672 mm. This is still probably within the limits of practical tolerances, but, none the less, it would alter the length of the standard mile. If the inch is to be altered to facilitate metric conversion, the standard yard and all other linear measures must be altered to suit. This is unlikely to be done, and, in any case, appears unnecessary, as the number of decimal places used in the conversion can always be chosen to suit the desired accuracy of the work in hand.

NOTES.

The Prime Minister on Production.

MR. CHURCHILL'S eagerly-awaited review of the nation's war production drew a full attendance at the House of Commons on Tuesday. There were two aspects, the Prime Minister stated, from which production must be considered, namely, the organisation of planning and control, and the conditions actually obtaining in the factories. The foundation of the high administrative control must be a single co-ordinated plan for the programmes of the three Services, based upon strategic needs. As Minister of Defence, he had prepared, for the first three months of this year, a revised general scheme which brought together the whole of the munitions production and imports programme. This scheme, approved by the War Cabinet in March, 1941, comprised a clear apportionment of the sources and costs of the material, and was mandatory on all the war departments. Its execution was the business of the Controller's Department of the Admiralty, the Ministry of Supply, and the Ministry of Aircraft Production; the work had been parcelled out, and it remained for them to do it. It had been suggested in various quarters that a Ministry of Production should be formed; this would be an additional complication, burden, and cause of delay. If the new Minister's control were merely nominal, without affecting the responsibilities of the heads of the supply departments, it would be a fraud on the public. If, on the other hand, the Minister of Production attempted to lay strong hands on the administration of the departments, they would confront him with a knowledge superior to his own, and great differences and internal friction would result. He admitted that there were still bottlenecks in the provision of certain precision tools, without which the full productive capacity of other tools could not be realised. Every effort was being made to overcome the shortage of skilled labour; he admitted that there had been difficulty in working night shifts to the full extent, under conditions of air attack; but it was the machine-tool position which had given rise to the complaints previously made in the House. It was not true that aircraft had been ordered from the United States on-British account without their proper equipment and spare parts; but there had been deficiencies of this kind among the French contracts which, when France collapsed, were taken over. These French-American aircraft had been subsequently put into service, and they were proving very satisfactory. The allegation had been made, Mr. Churchill continued, that "our people were only working up to 75 per cent. of their possible efficiency." That was a double expression of opinion; first, whether it was 75 per cent. or not; and, if so, 75 per cent. of what? He had tried to find a datum line, and had taken for that purpose the three months after Dunkirk. Since that period, there had been relaxation to the extent that Sunday work was practically eliminated and that brief periods of leisure had been permitted; but, in spite of this and of various difficulties with which they had had to contend, the Ministry of Supply output in the past three months had been one-third greater than in the three months of the Dunkirk period. In the past three months, more than twice as many field guns had been produced, and 1½ times the amount of ammunition, as had been turned out after Dunkirk. The shipbuilding in progress and in daily execution was greater than at any time in the last war; and, in aircraft, the increase above the spurt of a year ago was substantial. So far as labour was concerned, in the final two years of the last war, nearly 12,000,000 working days had been lost in labour disputes: in the 23 months of this war, the loss had been less than 2,000,000.

Iron and Steel Distribution Scheme.

The Steel Distribution Scheme of the Ministry of Supply has now been operating successfully for over a year. As stated on page 73, *ante*, the Control of Iron and Steel (No. 15) Order, 1941, which came into operation on July 17, has extended the Scheme to cover, in addition to steel, all iron products, except pig iron but including iron castings, with effect as from September 1. The total supply of both iron and steel is now allocated by the Materials Priority Committee to the various Government departments, and each department is responsible for dividing its allocation away to its consumers. With the object of simplifying the phraseology and form of the regulations so that iron producers and consumers should have no difficulty in understanding the new regulation, a new edition, the third, of the Iron and Steel Distribution Scheme booklet has been prepared and issued. In this booklet are set out the methods by which consumers obtain authority from Government departments to acquire and use iron and steel. A number of useful appendices are also included. The first deals with definitions of iron and steel, while the second consists of a specimen copy of the authorisation form, which is designated "Form M" and is issued to contractors and sub-contractors for specific purposes. There are a few minor exceptions to the use of Form M and these are referred to in a third appendix. In the fourth appendix is given a list of the names and addresses of Government departments which are empowered to issue authorisations for the acquisition of iron and steel for well-defined purposes, which are given in detail. The fifth and last appendix contains the names and addresses of Iron and Steel Control liaison officers and the areas covered by each. Copies of the booklet are obtainable on application to the Ministry of Supply, Iron and Steel Control, Ashorne Hill, near Leamington, Warwickshire.

The Location of Industry (Restriction) Order, 1941.

The President of the Board of Trade announced in the House of Commons, on April 28, that it had been decided to extend to the use of premises by private firms the powers of control over factory and storage accommodation recently conferred upon that department. The object of the control was to co-ordinate the demands of Government departments for such accommodation, and to ensure that their requirements were met with the minimum of disturbance to other essential production. This Control is now in full operation and is consulted by all Government departments and local authorities before premises are requisitioned. The demands for factory and storage space have now increased to such an extent that it has become necessary to prevent the uncontrolled use of existing accommodation which might be needed in the near future for more essential purposes. An incidental factor is the disorganisation which may be caused by unregulated movements of industry in the labour supply position in the areas affected to the possible detriment of vital war production. An Order has therefore been made, and comes into operation immediately, providing that no person may, without a licence issued by the Board of Trade, "(*a*) carry on at any factory or warehouse, having an area of 3,000 or more feet super, any trade or business not carried on there previously, or (*b*) carry on at other premises, having an area of 3,000 or more feet super, whatever their previous use, a business of production or storage." The Order, which is known as the Location of Industry (Restriction) Order, 1941 (S.R. and O., 1941, No. 1,100), does not apply to shops or to new buildings; and a general licence is being issued to permit premises to be used temporarily for storage purposes without a specific licence. An explanatory memorandum can be obtained either from the headquarters or regional offices of the Control of Factory and Storage Premises, Board of Trade, or from local Chambers of Commerce. Copies of the Order will be obtainable from H.M. Stationery Office or through any bookseller on August 5.

Magnetic-Storm Effects on Electric-Supply Systems.

A connection between magnetic storms and radio-transmission fade-outs and other troubles has long been recognised, but that sun-spot disturbances can also affect the operation of electric-supply systems is less well known. On March 24, 1940, a number of power systems in the United States and Canada experienced operating difficulties which coincided with the appearance of an intense magnetic storm. The area affected ranged from New England, in North Dakota, to New York, and extended to southern Minnesota and into Ontario and Quebec. The effect most commonly experienced was a voltage drop, ranging up to 10 per cent. Transformer banks, controlled by differential relays, tripped out in five cases, while, in one, transformer fuses were blown. Large increases in reactive kilovolt-amperes and other effects were also reported. In no case was there an actual interruption of service, but this was possibly because the day was Easter Sunday, when station loads were unusually light. Some particulars of the individual experiences of various power systems affected are given in the May issue of the Bulletin of the Hydro-Electric Power Commission of Ontario, which quotes from *Electrical Engineering*, the Journal of the American Institute of Electrical Engineers. In spite of the scientific data which have been accumulated, explanation of the exact effect of magnetic storms is still speculative. Analysis of field changes during such storms shows that they are presumably due to the induction effects of electric currents above the earth's surface. Two classes of field changes have been observed—those symmetrical about the earth's magnetic axis and those that are non-symmetrical. The first class may be attributed to a large ring current flowing in the outer atmosphere. During the first phase of a magnetic storm, this current flows from west to east; during the second phase, it flows from east to west. Although the greater part of the energy of magnetic storms is involved in this hypothetical ring current, the magnetic changes are not rapid enough to induce the high potentials which affect electrical systems. It is the non-symmetrical field changes which are responsible for troubles with communication and power lines. These changes are associated with currents flowing in the earth's atmosphere, probably at a height of 100 km. or so. They have their maximum intensity in the auroral zone, and may continue for several hours, but show rapid changes in intensity. The strength of these currents may exceed 1,000,000 amperes and changes of 100,000 amperes a minute have been observed. The current path may be 100 miles wide.

LETTERS TO THE EDITOR.

A THEORY OF THE KADENACY SYSTEM.

TO THE EDITOR OF ENGINEERING.

SIR,—In reply to Mr. Bannister's criticism of my article bearing the above title, it should be observed that since I equate the total energy in the system at one instant to the total energy in the same system at some later instant no consideration need be given to changes which may occur at any intermediate instant. It may be, however, that Mr. Bannister really means that he does not agree with me when I assume that the whole mass of escaped gas is moving with the velocity V_2, although he does not clearly state this. If this is so I would point out that the highest velocity, under controlled conditions, of the escaped gases occurs when the valve is first opened, since the pressure difference between the inside and outside of the vessel has then its greatest value. This velocity is, of course, easily determined. In the example which I quoted it is given by $223 \cdot 8\sqrt{c_p\ (T_1 - T_2)} = 1{,}530$ ft. per second. Actually, under uncontrolled conditions, the emergent velocity would be the acoustic velocity at the critical pressure of $0 \cdot 528 \times 74 \cdot 7 = 39 \cdot 4$ lb. per square inch absolute and temperature of

$$525 \left(\frac{39 \cdot 4}{74}\right)^{\frac{0 \cdot 4}{1 \cdot 4}} = 437 \text{ deg. F. abs.}$$

The velocity is then $V_2 = 223 \cdot 8\sqrt{0 \cdot 24(525 - 437)} = 1{,}025$ ft. per second. The value of V_2 which is obtained in my treatment is 1,060 ft. per second, so that I feel that I am still justified in accepting this as a first approximation, especially when the more probable figure for the initial velocity is that given by uncontrolled conditions, namely, of the order of 1,025 ft. per second.

I agree with Mr. Bannister that it would be more satisfactory if the treatment gave the duration of the depression and instant of its occurrence. I have, however, already dealt with the time of discharge from closed vessels in an article which appeared in *The Engineer* on July 21, 1939. From the treatment given there it is possible to determine the time taken for the pressure to drop to any assumed value. My main reason for submitting the article on the Kadenacy system was that at the time it was written there was considerable controversy regarding the existence of depressions of the magnitude claimed by the adherents of the system.

Yours faithfully,
E. W. GEYER.

James Watt Engineering Laboratories,
The University, Glasgow.
July 25, 1941.

SECTIONAL INTERESTS IN ENGINEERING INSTITUTIONS.

TO THE EDITOR OF ENGINEERING.

SIR,—It is noted with interest that in the leading article entitled "Sectional Interests in Engineering Institutions," which appears in your issue of July 18, on page 52, it is suggested that there should be at least an association of interests between the Institutions of Mechanical and Production Engineers and ourselves. The effectiveness of combined effort is, of course, a truism and needs no emphasis, especially in these days when the principle of "united we stand—divided we fall" has been so tragically demonstrated, and we have always ardently advocated such a policy. It is felt, nevertheless, that the suggestion may lead those who are not familiar with the policies of the respective Institutions to conclude that there is at present no measure of co-operation between them. This is far from being the case, and no better example could be quoted than the fact that since the outbreak of war each of these bodies, together with other engineering institutions, has been associated on the Mechanical Engineering Panel of the Central Register of the Ministry of Labour and National Service, in which capacity their co-operative effort has been directed towards the provision of the technical personnel required in the production of war material.

Although in its inception automobile engineering was rightly looked upon as just a side line of mechanical engineering, the growth of the automobile industry into the third largest in the country (peace-time assessment) has rendered necessary a separate body to safeguard its professional and technical interests, as the numerous other responsibilities of the Institution of Mechanical Engineers would not have permitted of its undertaking this additional duty. The best evidence of this lies in the fact that the Institution of Mechanical Engineers gives both advisory and financial assistance to the Automobile Research Committee of the I.A.E., which is charged with the duty of undertaking co-operative research for the automobile industry. Incidentally, many of the researches carried out under the auspices of this committee have been of almost equal value to the mechanical engineering industry. A further link between the I.Mech.E. and the I.A.E. lies in the endorsement, by the President of the I.A.E., of the Higher and Ordinary National Certificates in Mechanical Engineering issued jointly by the Board of Education and the Institution of Mechanical Engineers, in respect of automobile engineering subjects. The Institution of Production Engineers has recently come into line in this respect, a similar arrangement having been adopted between that body and the Institution of Mechanical Engineers.

Many further instances could be given of co-operative effort between these and other engineering institutions, but those quoted above will serve to show that while the growth of the respective branches of mechanical engineering renders necessary the existence of a separate representative body charged with the maintenance of its technical prestige, there is, nevertheless, a large measure of co-operation between those bodies which is not only a guarantee of maximum efficiency, but is also a safeguard against any considerable overlapping of interests and the consequent reduction in effectiveness which would arise therefrom.

I am, Sir,
Yours faithfully,
EDWARD B. HAGGERTY,
Acting Secretary.

The Institution of Automobile Engineers.
12, Hobart-place,
London, S.W.1.
July 26, 1941.

WAR-TIME INVENTIONS.*

By DR. H. J. GOUGH, F.R.S.

To a Service or Supply Department, adequate, efficient and speedy machinery for taking the fullest advantage of inventive genius is a matter of vital concern, especially during war. While, perhaps, no modern major war could be said to have been won by any particular invention, yet certain inventions could be instanced in the last war and, in fact, during the present war, which have exercised a large influence on the success of offensive and defensive operations. At any moment, some new idea may be evolved which may make a major contribution to the national war effort. It is in full recognition of this fact that the Ministry of Supply devotes a very great deal of time, effort and money to ensure that every inventor or proposer shall receive the most expert and sympathetic attention to his idea. The Inventions Section of the Ministry is no isolated entity, but a part of the great technical side of the Ministry concerned with scientific research and technical development. All three—invention, research and development—separately, and in combination, contribute to the common aim of bringing to the production stage new and improved weapons and equipment for the Army and, in some cases, the Navy and Air Force; new and improved industrial plant and processes; and a host of other civil and military needs.

"Invention" should not be confused with "Research and Development"; both are essential and neither can replace the other. While research and development can be systematically organised and pursued, history has conclusively shown that invention cannot be so treated; for, although many inventions have emerged as the result of long and laborious effort and thought on the part of the inventor, who has had his ultimate object in view throughout, others—which have had a profound influence on mankind—have resulted from a pure flash of genius or inspiration, without any previous systematic thought or study. It is our constant endeavour to harness to the national effort both types, and hence it is necessary to employ special and very personal methods of dealing with the inventor and his proposal.

The existence of a state of national emergency greatly stimulates the flow of suggestions, as might be supposed. During the period of rather more than 4½ years from the beginning of 1935 to August 31, 1939, rather less than 12,000 suggestions were received by the War Office. The actual numbers were:—In 1935, 1,370; in 1936, 1,772; in 1937, 2,416; in 1938, 3,609; and in the first eight months of 1939, 2,801. The sharp rise in 1938, due to the pre-Munich tension, will be noted. In September, 1939, 1,298 were received, and, during the last four months of 1939, the inflow totalled 6,103—more than twice that for the first eight months. The diagram on the opposite page illustrates the submissions, month by month, from the beginning of the war to the end of June, 1941. Particularly notable is the enormous increase induced by the evacuation of the British Expeditionary Force from the Low Countries, and the collapse of France, the suggestions put forward in June, 1940, reaching the remarkable total of 6,910.

At the outbreak of the last war, the civilian research and experimental staff of the War Department numbered less than 40 all told. But the lesson of the value of intensive research by highly trained scientific and technical staff had been well learnt, and hence, before the outbreak of the present war, the War Office (and, later, the Ministry of Supply) possessed five large and well-equipped laboratories, staffed by about 800 scientists including specialists in practically every branch of applied physics, chemistry and engineering, engaged in applying the very latest scientific principles to the weapons and defences, instruments and machines, equipment and stores needed to meet the complex demands of the fighting Services. In addition, we realised fully the need for availing ourselves of the research and technical resources of the universities and industry and had much work going on there, in addition to a great number of investigations conducted on our behalf at the other Government research laboratories throughout the country.

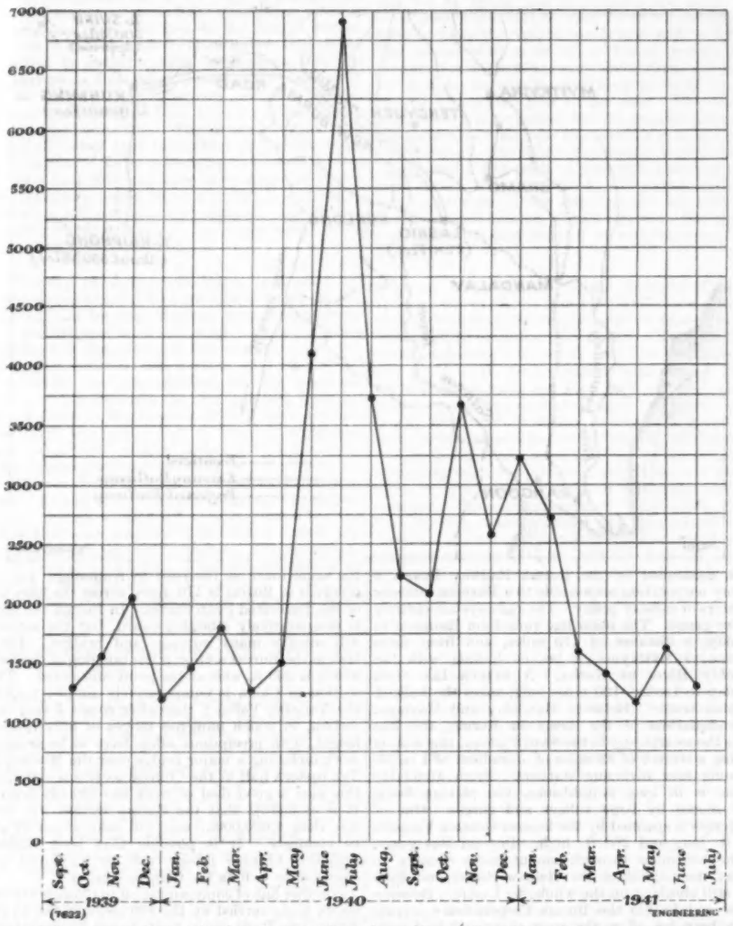
We who were responsible for planning were well aware of the flood of new demands for scientific and technical investigation which was certain to arise from the needs and problems of active service and of production and, as a result, a war emergency organisation was planned and came automatically into effect immediately on the outbreak of war. Under this scheme, a number of leading scientists, normally employed as professors at universities, at once joined our research establishments, together with a great number of more junior scientists and technicians, drawn from many fields of research and development. The Ministry also took over, for the duration of the war, several research laboratories complete, and certain departments of other laboratories. In addition, a steady recruitment of skilled staff was made to meet new needs as they arose. As the war progressed, many additional investigations were placed with specially selected universities and industrial research laboratories.

I would take this opportunity of recording the Ministry's high appreciation of the splendid and unfailing response which has been received to the demands made upon the universities, industry and private individuals for personal service and facilities in the war effort. At the present time, the scientific, technical and assistant staff in the direct employ of the Ministry numbers 2,700. About 100 major investigations are also being carried out, on our behalf, by highly skilled teams at universities, the research laboratories of industrial firms, and in the laboratories of the research associations. Approximately 250,000*l.* per annum is now being spent on extra-mural research of this kind. This scheme must represent one of the most comprehensive mobilisations of scientific and technical talent that has ever been attempted.

Broadly speaking, the main function of the Inventions Section of the Directorate of Scientific Research, Ministry of Supply, is to examine all inventions of which details can be obtained, with a view to their utilisation for the war effort. Details of inventions are usually obtained:—(1) by letters or other communications sent directly to the Ministry by independent inventors, in this country or anywhere in the world, who are anxious to make some contribution towards the successful prosecution of the war; (2) by interviews with inventors; (3) by suggestions made by members of H.M. Forces, forwarded through Service channels and frequently resulting from the inventor's appreciation, due to his service, of a requirement which is not met by, or of an improvement which can be made in, existing equipment; (4) by co-operation with the Patent Office, who notify the department of the number of any application likely to be of Service

* Address by the Director of Scientific Research, Ministry of Supply, to a Press Conference held in London on July 24, 1941. Abridged.

WAR-TIME INVENTIONS.



interest; (5) by co-operation with the corresponding department in the Admiralty and the Ministry of Aircraft Production, so that each supplies to either or both of the other departments details of such inventions as are likely to be of interest; (6) by co-operation with technical bodies established in this country by the Governments of German-occupied territories and temporarily resident here; (7) through the Inventions Board established in Washington, D.C., by the British Purchasing Commission, and the Inventions Departments of Dominions; (8) through military and naval attachés in foreign countries.

The proposals received are very numerous—over 50,000 have been submitted since the outbreak of the war—and range from the apparently trivial, such as a special construction of collar stud to such elaborate schemes as the design for a tank or a complete anti-aircraft defence system. Comparatively few valuable suggestions come from refugees; probably because most of those likely to produce good ideas are already employed in industrial or research establishments or are associated with the various exiled Governments, with which the department is in close contact. Many suggestions come from serving soldiers, for whom a simple procedure has been devised by agreement with the War Office. The soldier submits his proposal through his commanding officer; if it has merit, the comment of at least a brigade commander or area commander is obtained and sent to the War Office, who transmit it to the Directorate of Scientific Research. During June, 1941, about 4 per cent. of the proposals received were from serving men. The Inventions Board in Washington is the receiving station for proposals submitted by the public in the United States and Canada.

When a proposal is received, it is examined in detail by one of a staff of scientifically-trained examiners, who are specialists in the various subjects likely to be of interest to the Ministry, each proposal being examined, as far as possible, by an individual who is already familiar with the art to which it relates. If the proposal seems likely to be useful, it is sent to the appropriate user, development or research department, depending on the nature of the proposal and the extent to which it has been developed by the original inventor, with comments by the examiner on the technical merits and possible applications of the invention. Even during this preliminary consideration, every examiner considers the invention not only in the particular form in which it is put forward by the inventor, but also in its broadest aspect, with a view to determining whether it has possible Service uses not visualised by the inventor himself. In some cases, the examiner will suggest improvements, in order to increase the utility of the original proposal.

An invention for possible Service use is considered by the examiners and by other departments to whom it may be submitted from three main aspects, namely: whether it meets any Service requirements; whether, if there is a Service requirement for apparatus of the kind suggested, the actual apparatus put forward is technically sound; and whether the proposal presents sufficient advantages over existing equipment to justify, for example, the diversion of production capacity in order to produce the new article.

In some cases, outside departments to whom the invention is submitted for consideration do not, at first sight, regard it with favour. When, in such instances, examiners are not satisfied with the initial rejection of the proposal, they will return it for reconsideration, with comments on the reasons given by the outside department for the first rejection. When necessary and possible, the examiners obtain further information from the inventor, should they consider that this will be helpful in pressing the adoption of the proposal; thus, for example, the inventor may be given the opportunity of meeting criticisms made and of contributing towards the solution of problems arising from the proposal. If a proposal is recommended for adoption, the inventor is informed and, in some cases, he may be asked to collaborate in the development and production of apparatus based on his invention.

When a proposal is rejected, the inventor is at once informed that no further action is to be taken on it, but it is frequently not possible to give technical reasons for rejection without disclosing secret information. The inventor is always told, however, when his proposal is similar to one already investigated by the department, as this may save him expending needless time and work in further development. However, even if records may show that a proposal submitted is not novel, this in itself is not a ground for rejecting such a proposal, which is fully considered in the light of the ever-changing requirements of war. Furthermore, steps are taken in the case of proposals which are not of immediate use, but may be of use in the future, to ensure that they are periodically reviewed. In a few cases, the inventor is not satisfied with the somewhat terse decisions which the department is often compelled to give, but such cases are rare; most people realise that, during war, it is essential that secrecy shall be maintained. In this connection, it must be borne in mind that, in the absence of a specific investigation or of the personal knowledge of an examiner, the Ministry has no direct means of judging the *bona fides* of a correspondent, and that some of the alleged inventions put forward are submitted by enemy agents in the hope that the reply sent will disclose information useful to the enemy.

Inventors who call with details of their inventions are interviewed, if possible, by the expert on the subject to which the invention relates, but, in the absence of an appointment fixed after consideration of at least a brief outline of the proposal, the examiner most concerned may not be available. After a proposal has been considered either from a written communication or following a preliminary interview, the inventor may, if the proposal seems promising, be invited to further interviews to meet the department's military advisers and to discuss the proposal with them; or the examiner may arrange to take the inventor to the appropriate outside establishment for such discussion. Inventors are sometimes sent to the Ministry from overseas by Military or Naval Attachés or by the inventions departments of the Dominions. An examiner may arrange to visit an inventor, to inspect models which cannot readily be sent to the department or to witness trials, and may arrange for the military advisers in th Ministry and for representatives of the War Office als. to be present. Arrangements can be made, also, for expert interview and examination in other parts of the Empire and in friendly countries.

The examiners themselves are kept fully informed of current developments by personal contacts with members of other branches of the Ministry and of the War Office, and also by periodic visits to research and other outside establishments. They arrange, when possible, to be present at trials of new equipment connected with their special subjects, particularly trials of apparatus developed from proposals which they originally considered.

Close contacts are maintained with outside bodies such as the committees of learned societies, who are informed of Service requirements in so far as these can be defined, and are also given some details of proposals of a general nature which have already been investigated and found not to be suitable for adoption. Contact is also maintained constantly with the inventions and other sections of the Air Ministry, the Ministry of Aircraft Production, the Admiralty, the Ministry of Home Security, etc. By personal knowledge, visits, membership of committees, and in other ways, the officers of the department keep in close touch with such representatives of the scientific and technical world as the Councils of the Royal Society and of the Institution of Mechanical Engineers, the Advisory Council of the Department of Scientific and Industrial Research, and the Automobile, Aeronautical, and Civil Defence Research Committees.

Every month a list of all the proposals judged to have merit, and including a brief précis of the subject matter of each proposal, is circulated for information to the branches and establishments of the Ministry and the War Office, to the Scientific Research Departments of the Admiralty and the Ministry of Aircraft Production, to the Ministry of Home Security and to the Department of Scientific and Industrial Research. Thus, such proposals are brought to the notice of specialists who may find possible applications not appreciated by the examiners.

The Directorate has facilities for initiating research work, for example, in co-operation with the research departments of universities; and, where it is considered desirable, arranges for research on and the development of a useful proposal directly under its own control. Records are kept of each proposal and proposer in card indexes, to ensure that the priority rights of the true and first proposer of an adopted invention are preserved, irrespective of whether or not the inventor has himself applied for patent protection. It is most important that the department should deserve and enjoy the full confidence of the inventor or proposer, and that he should feel assured that his interests are being carefully watched. For this purpose, elaborate records are an essential feature of the organisation.

In the case of patent applications which have been

brought to notice either by the inventors themselves or through the Patent Office, copies of the provisional and complete specifications are examined, to determine not only whether the invention is suitable for Service use but also whether publication of the specification should be prohibited under the Defence Regulations to prevent details reaching the enemy. It may sometimes be necessary to prohibit publication of the specification of an invention which is not taken up, because the invention is similar to one already in use. The examiners, in addition to scientific and technical experience, have the legal knowledge and, in many cases, the experience to deal with problems arising under the Patent and Emergency Acts and the Defence Regulations.

The awards made to inventors or proposers in respect of suggestions which are adopted are based upon their originality and value, which is clearly determined by technical merit and the service rendered to the country; and by the extent of the use made of the suggestion or device, which is readily ascertained from the records of production or application which are kept by the departments concerned. The adjudicating authority, in the first place, is the Ministry of Supply Committee on Awards to Inventors, of which the present Director of Scientific Research is chairman, and which comprises representatives of the Ministry of Supply, the Treasury, the Admiralty and the War Office. They have power to award, without reference elsewhere, sums up to 1,000*l*. For recommended claims in excess of that amount, the matter is referred to the Treasury. There is also the inter-departmental Central Awards Committee, to which any dispute can be referred; but there is no record of any case having been referred to this committee since the last war—a most satisfactory tribute to the relations existing with inventors. Where payments of royalty on inventions are concerned, usually little difficulty arises, the matter being settled by mutual arrangement between the Ministry of Supply and the owner of the patent. Should any dispute arise regarding the validity of a patent, the patentee always has the right to apply to the Law Courts; but no such case has arisen within recent years.

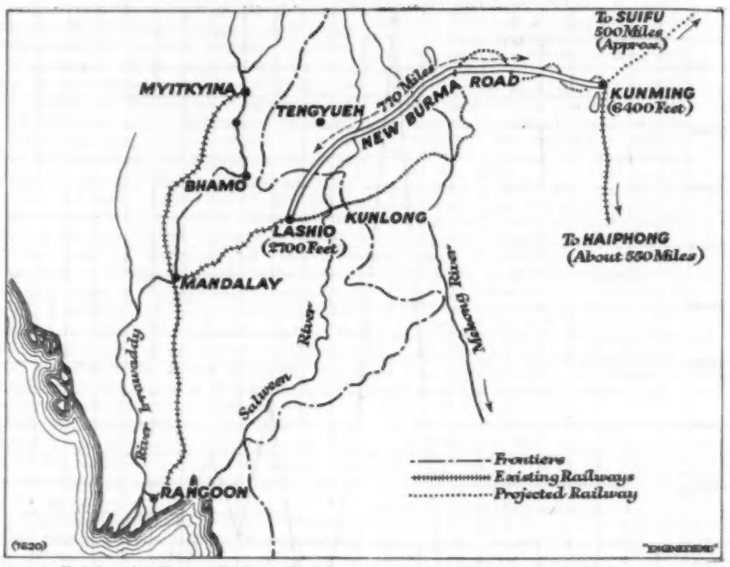
COMMUNICATIONS BETWEEN BURMA AND CHINA.

THE developments of the past week in French Indo-China, and the Far East generally, though they are obviously linked with the common policy of the Axis Powers, may be regarded also as but one more step in the Japanese expansionist movement which began in 1894-5, when the war with China enabled Japan to acquire the island of Formosa and a virtual control of Korea. The south-westerly extension of Japanese influence along the shore of the South China Sea has progressed more rapidly in the past four years, and it was evident, even before the collapse of France a year ago, that the position of French Indo-China was becoming increasingly precarious. The main threat behind the latest Japanese manœuvre, of course, is to the communications by land between Burma and China, by means of which the Government of General Chiang-Kai-Shek has obtained necessary supplies since access by sea was cut off. These various routes—there are four between Rangoon and the Chinese frontier—all present conditions of some difficulty, because of the character of the terrain; and their improvement, which may be regarded as probable important items in the post-war re-settlement of the Far East, will certainly involve some unusual engineering problems.

The four lines of communication mentioned are indicated on the accompanying map; they are (1) by railway to Lashio and thence by road; (2) by road all the way from Rangoon, following the same route; (3) by river to Bhamo and thence by road; and (4) by rail to Mandalay or Katha, thence by river to Bhamo, and thence by road. On the Chinese side, there is only one first-class route in existence, the "Burma Road" to Kunming, but a second line will be available when the new railway from Lashio to Kunming is completed. Many pack routes also exist, which have long been used for trade between Burma and China. There is air communication between Rangoon and Chungking, via Lashio, a passenger and postal air service being operated by the Chinese National Aviation Corporation. Air freight services from Lashio or Myitkyina to China, which would relieve pressure on the Burma Road, have been considered, but have not yet been put into operation.

The focal point of Burma's communications is the capital, Rangoon, situated on the Hlaing or Rangoon River, some 20 miles from its entrance into the Gulf of Martaban. Almost the whole of the trade of Burma passes into and out of Rangoon, and, to cope with this trade, reconstruction and improvement of the harbour facilities at Rangoon took place about 12 years ago and again within the last two or three years. These have been described from time to time in ENGINEERING. Rangoon is also the headquarters of the Burma railway

BURMA-CHINA COMMUNICATIONS.



system, controlled by the Burma Railway Board, a statutory corporation responsible to a Burman minister on matters of railway policy. The railways are entirely of metre gauge. The main line runs from Rangoon to Mandalay, a distance of 440 miles, and from there continues to Myitkyina, a branch linking with the Irrawaddy River at Katha. A branch line from Mandalay to Lashio, 120 miles long, takes the bulk of the China traffic. Between Mandalay and Maymyo, the headquarters of the Army in Burma, the line mounts the escarpment to the Shan Plateau, this section including a stretch of 13 miles of a gradient of 1 in 25, containing four reversing stations. From Mandalay the line is in long switchbacks, the plateau being deeply scored by large valleys and gorges. One of these gorges is spanned by the famous Gokteik Viaduct, 2,260 ft. long and 260 ft. high. Beyond this gorge, the line continues through mountainous country to Hsipaw, the capital of the Hsipaw State, and from there, still climbing on the whole, to Lashio. Between Hsipaw and Lashio the Burma Corporation's private railway branches off to the great silver and lead mine at Bawdwin, and the plant at Namtu. Lashio, the terminus, is the administrative headquarters of the Northern Shan States.

A first-class motor road runs from Rangoon to Lashio, following much the same route as the railway, and at Lashio the famous Burma Road to Kunming begins. The section in Burma, 120 miles long, is a mountain road, but in good condition. The total distance from the railhead at Lashio to Kunming is 738 miles, and the journey takes, on an average, five days for private cars and seven for motor lorries. The section in China to Kunming, the capital of the province of Yunnan, was opened in 1938 and has remained open since then, apart from temporary stoppages due to landslides and Japanese bombing. The road crosses the Salween and Mekong rivers by suspension bridges, and contains some very steep gradients, ; particularly that beyond the Mekong Valley, where it rises in a short stretch from 4,000 ft. above sea level to the great height of about 7,500 ft. In view of the limitations of road traffic, which is not suitable for all types of goods, the Chinese Government has consistently pressed the need for railway communication between Burma and China, and early this year the decision was taken to build a railway from Lashio to link up with a railway from Kunming, on which work had already been started.

The question of railway communication between Burma and China has been under discussion for many years, having been first examined in the 'nineties. Some three years ago, the construction of the whole line both in Burma and in China was under consideration by private commercial organisations, but this came to nothing, as it was doubted whether the line would pay from the point of view of private investors. Similar considerations precluded the Government of Burma from undertaking the project from their own resources; but it has now been decided that, as a long-term project, the railway will be constructed from funds provided by H.M. Government in the United Kingdom, the Government of Burma to be given the option to acquire the railway at a later date. The railway will follow a different alignment from the road for about two-thirds of its length, thereafter following much the same route as the road to Kunming. The length involved in Burma is 110 miles, across the hilly plateau of the Federated Shan States. In Burma the first half is comparatively straightforward, but the second half will involve many cuttings and bridges. The chief task in the Burma section is the bridging of the Salween, which is 500 ft. wide at the point considered. The first section in China is comparatively simple, running up the Namting Valley; thereafter comes a very difficult section, in which immense ranges of hills 7,000 ft. in height, with precipitous sides, have to be crossed, the work including a major bridge over the Mekong River. The eastern half of the Chinese section is easier, and on this part a good deal of work has already been done. It is estimated that the Burma section will cost not less than 2,000,000*l*., and will take about two years to complete. It is possible that both skilled and unskilled Chinese labour will be employed on the Burmese as well as the Chinese section.

Another line of communication to China is via Bhamo, goods being carried up the 870 miles of the Irrawaddy River from Rangoon on floats towed by steamers. The journey by boat takes 9 days to 10 days, but this time can be shortened by taking the goods by rail to Katha and transferring them to the river at that point. Bhamo lies on the old trade route from Burma to China, which followed a pack road via Tengyueh to Kunming. In spite of difficulties, trade flourished on this route for many years, and as far back as 1894 a convention with China was concluded, which dealt with mutual trade and the fostering of trade relations between Burma and Yunnan. The Bhamo-Tengyueh route is not passable for motor lorries, but a motor road runs from Bhamo via Panghkam in Burmese territory, to join the Burma Road near the frontier. The first section of this, though mountainous, is in fair condition, but the second section, which is on comparatively low ground along the River Shweli, is indifferent, being liable to flooding in the rains.

CONTROL OF MACHINERY PLANT AND APPLIANCES.—Under the Machinery, Plant and Appliances (Control) (No. 4) Order, 1941 (S.R. & O. 1941, No. 1063, price 1d.), published on July 26, new classes of machinery, plant and appliances, subject to licence by the Board of Trade, are added to those listed in the schedules to previous Orders, and certain of the classes already included are amended. Further, it has been laid down that machinery, plant and appliances may be supplied without licence, under the Orders, to a public-utility undertaking only when such supply can be made with the licence, or under the authority, of a Government department. The complete schedules are listed in the new (No. 4) Order, and in the (No. 2) Order (S.R. & O. 1940, No. 1363); the Machinery, Plant and Appliances (Control) Order, 1940 (S.R. & O. 1940, No. 2179); and in the (No. 3) Order (S.R. & O. 1941, No. 778), each of which is obtainable, price 1d., from H.M. Stationery Office, York House, Kingsway, London, W.C.2. Application forms for licences to acquire machinery, plant and appliances falling within the schedule to the Orders may be obtained from the Industrial Supplies Department (Machinery Licences Division), Board of Trade, 1-6, Tavistock-square, London, W.C.1.

LABOUR NOTES.

A SMALL committee has been set up by the Government to investigate as part of the man-power problem the present use of skilled men in the Armed Forces. Complaints have been made by trade unions that skilled men needed in industry have been taken into the Forces and given duties that do not utilise their skill. Both the Trade Union Congress and the British Employers' Confederation have been invited to supply evidence to the committee. The General Council have replied to the effect that the collection, through trade union channels, of facts concerning thousands of men must take a long time and they have suggested that a simpler procedure would be to give the T.U.C. representations on the committee of inquiry. The British Employers' Confederation, it is understood, have reached a similar conclusion.

The Ministry of Agriculture states that after full discussion, at meetings of the Agricultural Wages Board, of the resolution by the workers' representatives to increase the national minimum wage for regular adult male workers in agriculture to 60*s.* a week, there was no agreement between the workers' and employers' representatives. In the opinion of the members appointed by the Ministry, the arrangements made on wages and prices in the summer of 1940 have not had time to work themselves out in farming costs and returns, and in their view, a further period should be allowed to elapse (say until the week beginning November 3) before a decision is asked of the board on this proposal. At the same time, the appointed members are, as at present advised, of opinion that after the harvest of 1941 some increase in the national minimum wage may be proper and possible. The materials necessary for any calculation of the amount should be available at the meeting in November. But, the Minister's statement adds, this opinion of the appointed members, on the course to be adopted by the board, should not in any way prejudice the exercise of their powers by the county committees in dealing with wage questions in their areas.

The Ministry of Labour and National Service states that on July 1 the official cost-of-living index figure was 99 points above the level of July, 1914, compared with 100 points on May 31. For food alone, the index figure on July 1 was 67 points above the level of July, 1914, compared with 70 points on May 31, the decline being due to decreases in the price of fish and eggs. Among items other than food, there were slight increases in the prices of clothing and clothing materials, partly owing to the effect of the purchase tax, and there was a general increase of 10*d.* a ton in the price of coal at the beginning of June. Since the purchase tax came into operation in October last, the resulting increases in prices have raised the cost-of-living index figure by approximately 5½ points.

The following editorial note appears in the July issue of *Man and Metal*, the journal of the Iron and Steel Trades Confederation:—"Anyone who has been around the bombed areas of our blitzed towns cannot fail to be struck by the sight of tons of huge twisted steel girders left rusting amidst the otherwise tidied-up ruins. There they stand, and no one seems to bother about them; yet within a stone's throw one can sometimes see gangs of men laboriously chiselling away digging up unused tramlines. Half the effort put into that would give three times the result in scrap if these men were employed getting the girders away. There may be all sorts of reasons for this, but if it is simply a question of ownership rights, surely there is no need to hold up this first-class steel scrap while the question of compensation or payment is being settled. The salvage authorities should really try to imagine the effect of seeing these things on the mind of the housewife who is being continually reminded by the Press and radio of the support she is giving to Hitler by keeping her old flat-irons and unused pots and pans in the cupboard under the stairs."

According to the Ministry of Labour and National Service a further 3,000,000 men and women will be called upon to register for essential war work before the end of the year. In addition to women born in 1910 to 1916 inclusive, men born in 1895, 1896 and 1897 will be required to register. The demands for manpower, it is stated, are so heavy that further age groups of women will probably have to register, and much more drastic action may be necessary.

In the agreement between the shipbuilding employers and shipyard trade unions on the U.S. Pacific coast, mentioned in these notes a week ago, provision is made for the working of the three-shift system. The regular starting time of the day shift is to be 8 a.m. except where in any locality traffic conditions render it desirable to start at an earlier hour, but in no event before 7 a.m. The regular starting time of the day shift is to be recognised as the beginning of the 24-hour workday period. The first or regular daylight shift is to last for 8½ hours, less 30 minutes for meals in the employers' time, and be paid for at a rate equivalent to eight times the regular hourly rate with no premium. The second shift is to be an 8-hour period, less 30 minutes for meals in the employers' time, and payment for it is to be a sum equivalent to eight times the regular hourly rate plus 10 per cent. The third shift is to be a 7½ hour period, less 30 minutes for meals in the employers' time, and payment for it is to be a sum equivalent to eight times the regular hourly rate plus 15 per cent. For work on any shift less than the full shift period, the pay is to be the corresponding proportionate part of the pay for the full shift period provided such amount be not less than the minimum pay otherwise provided for in supplementary agreements."

In an Order issued by the German Minister of Labour, attention is drawn to provisions already in force prohibiting the employment of women on work calculated to prejudice their health. Exemptions from these provisions, it is stated, should be granted only in individual cases where particularly strong grounds for exemption exist and then only provided that the women concerned are thoroughly protected against health risks. In particular, exemption permits may in no circumstances be granted for the employment of women in the transportation of materials in any kind of building work, or in clearing, excavation and transport work or preparatory work in china-clay pits and quarries. The same applies to the clearing, excavation, loading, transportation and preparation of raw materials in sand and clay pits. The labour inspection officers are empowered to issue the necessary instructions to the employment officers not to supply women for the kinds of work specified.

Under a German Order relating to glass works no worker under 18 years of age may be employed at furnaces or on grinding work of any kind, and no worker, irrespective of age, may be employed on sand blasters, stone crushers and grinding mills or in pot-furnace rooms or refractory-brick manufacturing rooms in glass works unless he is certified in writing by a State factory surgeon as fit for the work in question. The medical examination of workers engaged for sand blasting or for work on stone crushers and in grinding mills or pot-furnace rooms and refractory-brick manufacturing rooms, must be supplemented within a maximum period of six weeks by the taking of an X-ray photograph.

The employer is made responsible for seeing that workers under 18 years of age employed on glass furnaces, and all workers employed in the production of mixtures with a lead content or in the manipulation of colours with a lead content, are examined by the competent surgeon at least once in every six months—and that workers employed on stone crushers and grinding mills and in pot-furnace rooms and refractory-brick manufacturing rooms are so examined not less than once in every two years. The medical examination of workers employed on stone crushers and grinding mills and in pot-furnace rooms and refractory-brick manufacturing rooms must be completed by the taking of an X-ray photograph.

An Order made the German Commissioner for the occupied territory of the Netherlands regulating wages, salaries and other conditions of employment states that no collective agreement may contain a clause providing for a change in wage rates on account of circumstances not directly connected with the relationship between employer and employed. Any clauses of the kind in a collective or individual contract of employment are cancelled. Further, any new collective agreement or amendment of an existing agreement entailing an increase in wage rates must be submitted to the authorities for approval.

Moreover, if the Secretary-General of the Ministry of Social Affairs considers it to be necessary "in the workers' interests," he may fix wages and other conditions of work which are not governed, or are, in his opinion, improperly governed by a collective agreement; his decision has binding effect. He may delegate this power to an authority subordinate to him, and has already, in fact, issued an Administrative Order investing a board of Conciliators with his powers in this respect.

MOTOR AMBULANCES FROM AMERICA.—Three motor ambulances presented by railwaymen in the United States were handed over to the British-American Ambulance Corps on July 24 at Euston station by Sir Thomas Royden, chairman of the London Midland and Scottish Railway.

RESISTANCE OF CAST IRON TO DEFLECTION UNDER LOAD AT HIGH TEMPERATURES.*

By L. W. BOLTON, A.M.I.Mech.E.

ORDINARY grey cast iron fails at high temperature through growth and scaling, but special irons have been developed in recent years which possess resistance to a marked extent to both these effects. The extended application of these irons in industry has made it desirable to have some information regarding their resistance to deformation under prolonged application of light loads at high temperatures. The work described in this report was carried out with a view to supplying some of this information, and since the results of quantitative creep tests at high temperatures are extremely difficult to interpret for purposes of design, it was felt that the work should not be confined to actual creep tests on the special irons, but rather should be designed with a view to studying the influence of composition, structure and casting conditions on this phenomenon. In this way it was hoped to obtain data on the relative resistance to deformation under load, at high temperatures, of various types of heat-resisting cast irons which are now available.

Most heat-resisting cast irons have a fine graphite structure, and some owe their qualities to the presence of an abnormally high silicon content (*i.e.*, more than 4·5 per cent.). Others are austenitic, and consequently are far less rigid at room temperature than pearlitic or ferritic irons. It is sometimes desirable that the irons should contain a moderate quantity of phosphorus, to improve the castability of the metal. For these reasons, special attention has been given in this work to the influence of graphite size, variations in silicon and phosphorus contents, and to alloying employed to the extent of rendering the structure of the iron austenitic. Some data on carbon steels of varying carbon content have also been obtained. For the purpose of this exploratory work, a method of testing has been developed which consists essentially of transverse-loading a bar of standard dimensions at one end while the other end is rigidly held, the stressed portion of the bar being held at a predetermined constant temperature. Details of the apparatus used and the method of carrying out the test are described below. After consideration of the various industrial applications in which cast iron is used at high temperatures, it was decided that information was most needed on its resistance to deformation at between 800 deg. C. and 900 deg. C. A temperature of 850 deg. C. was, therefore, chosen for the investigation.

Apparatus Used and Method Employed in the Test.—The layout of the apparatus is shown in Fig. 1, on the next page. The specimen *d* is a bar 7 in. long and 0·6 in. in diameter, reduced to 0·5 in. in diameter for a distance of 1 in. near one end, for the purpose of localising the stress. One end of the bar is rigidly held in a heavy heat-resisting nickel-chromium-alloy holder *b*, clamped to the base of the apparatus by means of stout cast-iron brackets. The test piece is loaded at the free end with weights *e*, and a system of levers *f* amplifies the movement of the pointer at the end in the ratio of 10 to 1, this movement (*i.e.*, deflection at the free end) being recorded on a moving drum *g*. In order to eliminate the effects of vibration, the whole apparatus is suspended on springs *h*. The test-piece is raised to, and maintained at, the required temperature by means of a resistance furnace *a*, well lagged with kieselguhr. On account of the massive size of the holder *b*, the rest of the apparatus was also thoroughly insulated with kieselguhr and slag wool *c*. The temperature of the specimen was obtained by means of a platinum/platinum-10 per cent.-rhodium thermocouple, the hot junction of which could be moved along the bar for a distance of 1 in. The furnace temperature was not thermostatically controlled, but the variations in temperature did not exceed ±7 deg. C., and these variations were found to be without effect on the manner in which the bars deflected under load.

In carrying out the test, the furnace was slowly raised to the required temperature, and a steady temperature state was reached in approximately 5 hours from the time of switching on the furnace. During this heating-up period, the test bar was supported at the free end to prevent any sagging under its own weight. The weights used at the free end were such that the transverse stress at the narrowed part of the bar near the fixed end could be increased in steps of 0·1 ton per square inch from 0 tons to 2 tons per square inch. The effect of applying a load at the free end of the bar was to cause a fairly rapid rate of deflection for the first three or four hours, but after this

* Communication from the British Cast-Iron Research Association, entitled "A Study of Some of the Factors Affecting the Resistance of Cast Iron to Deflection under Load at High Temperatures," presented to the Iron and Steel Institute for written discussion (not later than September 15, 1941). Abridged.

the rate of deflection gradually decreased and then remained constant. At the end of a 24-hour period, the load was stepped up by an increment of 0·1 ton per square inch, which was maintained for another 24 hours, and this process was repeated until the bar had bent through an angle of approximately 10 deg. It is worthy of note that even the most brittle of cast irons, such as the high-silicon and high-phosphorus irons, were found to deform to this extent at 850 deg. C. without breaking.

The tests carried out showed that the section of the bar as cast had a considerable influence on the manner in which the test-piece was deformed under load at high temperatures. It was found, for instance, that test-pieces machined from thick cast sections were less rigid than those machined from thin sections of the same iron, and, in interpreting the results, this factor has to be taken into consideration.

The Influence of Silicon.—The ordinary common grey iron of medium silicon content, often used at high temperatures, usually fails ultimately from scaling and growth. Norbury and Morgan have shown that, if the graphite can be kept in a fine state of division, high-silicon cast irons have resistance to scaling and also a marked resistance to failure from growth. Such irons, having a silicon content of approximately 5 per cent., together with a fine graphite structure, are known as Silal. The influence of additions of silicon to cast iron is well known, the matrix becoming harder and more brittle with increasing silicon. The eutectic carbon content is reduced and the high-silicon cast irons with a silicon content of 14 per cent. to 16 per cent., used at present mainly for their resistance to chemical attack, contain usually less than 1·0 per cent. of total carbon, even when melted in contact with carbon, *i.e.*, in the cupola.

A series (A) of bars with increasing silicon contents, ranging from 2 per cent. to 14 per cent., was tested, the actual compositions being given in Table I. The

TABLE I.—*Compositions of Irons, Series A (Increasing Silicon Contents).*

No.	Total Carbon.	Si.	Mn.	S.	P.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	3·10	1·98	1·16	0·034	0·022
2	3·33	3·28	0·75	0·019	0·067
3	2·15	6·62	1·19	0·028	0·034
4	2·67	7·16	1·17	0·031	0·031
5	1·63	9·32	1·19	0·011	0·100
6	1·07	13·77	1·09	0·014	0·125

cast size of the bars was 0·65 in. in diameter. All the bars were cast in green-sand moulds from metal melted in a coke-fired crucible furnace. The crucible charges were made up from mixtures of Swedish white iron (3·8 per cent. total carbon), Armco iron, ferro-silicon (10 per cent. silicon) and ferro-manganese (80 per cent. manganese) to yield the desired composition. After the charge had melted down, the metal was superheated for approximately 15 minutes and then skimmed and poured.

It was found that silicon exerts a stiffening influence on cast iron at the temperature of the tests. The iron containing 6·62 per cent. of silicon is of the Silal type and contains graphite in a finely divided state, as will be seen from the structure (Fig. 4, opposite). The graphite flakes in the 13·77-per cent. silicon iron (Fig. 7, opposite) are also small, but those in the other two high-silicon irons (Figs. 5 and 6) are relatively coarse. This fact will be examined later in the section on graphite size. The sections shown in Figs. 4 and 5 have been etched in picric acid, and those seen in Figs. 6 and 7 in 40-per cent. hydrofluoric acid, 20 per cent. nitric acid in glycerine. Fig. 2, on this page, shows deflections plotted against silicon contents at a load of 0·5 ton per square inch at 850 deg. C., *i.e.*, the total deflection at the end of the fifth day of the test in each case. This shows clearly the increase in the rigidity of the irons as the silicon content is increased.

Air was able to enter the furnace during the tests, and this led to some scaling and growth, especially in the case of the low-silicon irons. Wastage of the specimens through scaling may be a contributory cause of the lack of rigidity of the two low-silicon irons. It was noted that the deflection of the iron containing 3·28 per cent. of silicon was only slightly greater in the early stages of the test than that of the specimen which contained 6·62 per cent. of silicon. The sudden falling-off in the rigidity in the case of the low-silicon bar as the test proceeded and as the load increased may be explained partly by this deterioration of the metal under heat. The scaling of the Silal bar was only superficial, as was also that of the other high-silicon irons. An interesting point is that these high-silicon irons, which, as already mentioned, are extremely brittle in the cold, were found to bend under prolonged stress at 850 deg. C. The bar containing 13·77 per cent. of silicon gave a permanent deflection of 0·86 in. at the free end of the test-piece under a stress of 1·7 tons per square inch after 12 days at this temperature. (The stress was increased at the rate of 0·2 ton per square inch every 24 hours after 0·7 ton per square inch had been reached.) The results of these tests show that additions of silicon of the order of 7 per cent., and upwards, considerably increase the resistance of cast iron to deformation under load at high temperatures.

The Influence of Phosphorus.—In examining the influence of phosphorus, a base cast iron containing 5·5 per cent. of silicon was used, as this material scaled only slightly and had a very small growth. In this series (B) of bars tested, the phosphorus content varied between 0·4 per cent. and 1·1 per cent. The as cast size of the bars in this case was 0·875 in. in diameter. The bars were produced from a mixture of mild-steel scrap, refined pig-iron and ferro-silicon (10-per

Fig.1.

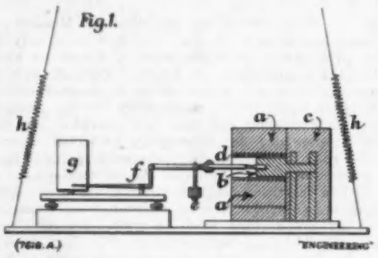


Fig.2.

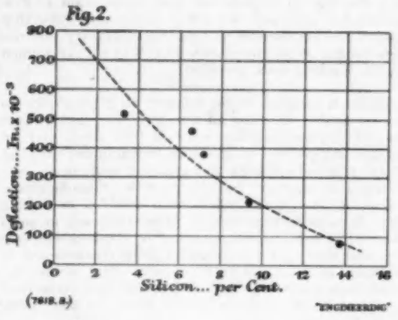
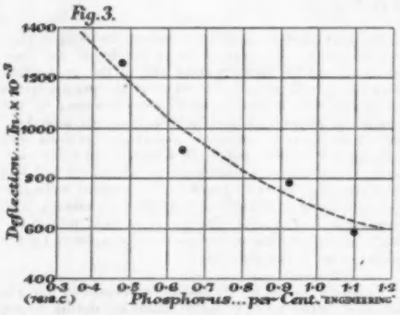


Fig.3.



cent. silicon), melted in coke-fired crucible furnace. Additions of ferro-phosphorus (20 per cent. phosphorus) were made to the molten metal in the crucible before each bar was cast, the metal being returned to the furnace after each addition to bring it back to a suitable temperature for casting. The bars were cast in green-sand moulds, and the pouring temperature was kept as uniform as possible throughout the series.

It was ascertained that additions of phosphorus progressively increased the stiffness of the metal at high temperatures. This stiffening influence is clearly shown in Fig. 3, where deflections are plotted against phosphorus contents for a stress of 0·7 ton per square inch at 850 deg. C., *i.e.*, total deflection of the specimen at the end of the seventh day of the test in each case. With the exception of the phosphorus content, the analyses of the bars were very similar, and the microstructures were also very much alike. All the bars scaled only superficially, so that it would appear that the differences in rigidity are entirely due to the difference in phosphorus content. It was noted, however, that the graphite size of the specimen containing 1·100 per cent. of phosphorus, the most rigid under test, was slightly coarser than that of the other bars in this series.

In order to examine the influence of phosphorus on cast iron of lower silicon content than Series B, two ordinary grey-iron bars (Nos. 11A and 12A) containing approximately 3·2 per cent. silicon, but with widely differing phosphorus contents, were tested (Series C). The as-cast size of the bars was 0·65 in. in diameter. They were produced under similar conditions to the bars in Series A, and an addition of ferro-phosphorus (20 per cent. phosphorus) was made in the case of bar 12A.

The analyses are shown in Table II. The higher-phosphorus bar was found to be more rigid than the one with low phosphorus, although the difference in rigidity in this case is less marked than would be expected from the results obtained in Series B. Both bars in Series C, however, scaled on the surface and suffered from growth, and it is likely that this to some extent masked the influence of the differences in phosphorus content. The tests on bars of Series B and C do, however, show that additions of phosphorus increase the resistance of cast iron to deflection at 850 deg. C. over the range of silicon contents of the metal, 3·18 per cent. to 5·5 per cent.

The Influence of Graphite Size on Rigidity.—In order to examine the influence of graphite size, bars were cast in two different sizes from four different compositions. In each case the bar cast to the larger original diameter contained graphite in larger flakes than the small-cast diameter bar. The metal was melted in a coke-fired crucible furnace and cast into green-sand moulds. Each pair of bars, of large and small diameter, was cast from the same crucible of molten metal. The components of the charges were the same as those employed in Series A, with an addition of ferro-phosphorus in the case of the charge from which bars 12A and 12B were cast. The pouring temperature and moulding conditions were very similar for each pair of bars, and as far as possible were kept uniform throughout the series. Differences in structure in the last two different sizes of bar of the same composition were due to the influence of the section on the rate of cooling. The actual analyses of the bars, constituting Series D, are given in Table II. Specimens for testing at 850 deg. C. were turned from these bars.

TABLE II.—*Compositions of Irons, Series D (Small- and Large-Diameter Bars).*

No.	Cast Diameter.	Total Carbon.	Si.	Mn.	S.	P.
	In.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
11A*	0·65	3·33	3·28	0·75	0·019	0·067
11B	1·75					
12A*	0·65	3·18	3·18	0·84	0·040	1·320
12B	1·75					
13A	0·65	2·53	5·75	1·06	0·048	0·036
13B	1·20					
14A	0·65	2·67	7·16	1·17	0·031	0·031
14B	1·20					

* Bars 11A and 12A constitute also Series C, high and low phosphorus contents.

It was found that the smaller-cast bars resist deflection at 850 deg. C. better than the larger bars of the same composition in each case. The large-cast diameter high-phosphorus bar is more rigid than the large-diameter low-phosphorus bar, showing that the phosphorus has a stiffening influence, even in large-diameter bars. The finer graphite size of the 0·65-in. diameter bars (Figs. 8 and 10) compared with the larger-cast diameter bars (Figs. 9 and 11) will be noted. All the specimens were etched in picric acid. The tests showed that, for the same composition, a cast iron with coarse graphite has less resistance to deflection at high temperatures than an iron containing fine graphite. Both silicon and phosphorus increase the stiffness of coarse-graphite cast irons at the temperature of the tests.

An examination of the structures of the bars in the preceding series, however, in relation to their rigidity and composition, shows that small differences in graphite size are unimportant and have less influence on resistance to deformation, at the temperature of the test, than relatively small changes in composition. It will be seen, for example, that bar 4, the structure of which is shown in Fig. 5, was more rigid than bar 3, with the structure depicted in Fig. 4. Here an increase of approximately 0·5 per cent. of silicon has more than offset the influence of the coarser graphite structure in bar 4. An examination of the results obtained from the bars of Series D, however, shows that large differences in graphite size have a greater influence on rigidity than comparatively large differences in composition. It will be seen that bar 11A, having the structure shown in Fig. 8, was more rigid than bar 12B, which had the coarse graphite structure illustrated in Fig. 11, but which contained 1·2 per cent. more phosphorus. Bar 13A resisted deflection more successfully than bar 14B, although the latter contained approximately 1·4 per cent. more silicon.

The Rigidity of Carbon Steels at 850 deg. C.—Three plain carbon steels, forming Series E, were tested in

RIGIDITY OF CAST IRON AT HIGH TEMPERATURES.

FIG. 4. SILICON 6·62 PER CENT. × 75.

FIG. 5. SILICON 7·16 PER CENT. × 75.

FIG. 6. SILICON 9·32 PER CENT. × 75.

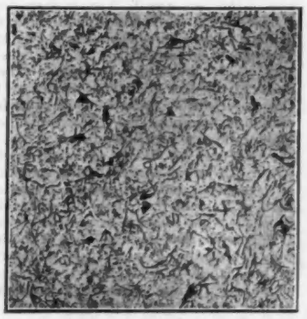


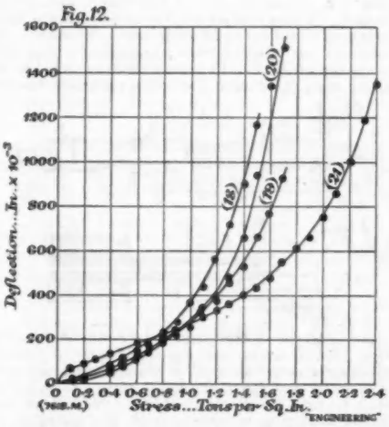
FIG. 7. SILICON 13·77 PER CENT. × 75.

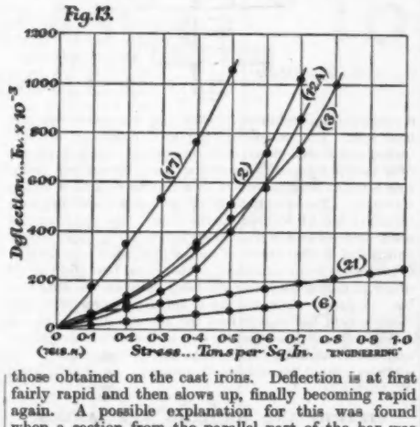
FIG. 8. SPECIMEN 11A. × 75.

FIG. 9. SPECIMEN 11B. × 75.

FIG. 10. SPECIMEN 12A. × 75.

FIG. 11. SPECIMEN 12B. × 75.





order to obtain a comparison between their resistance to deflection at 850 deg. C. and that of cast iron. They had typical low, medium and high carbon contents,

TABLE III.—*Compositions of Steel Bars, Series E (Increasing Carbon Contents).*

No.	C.	Si.	Mn.	S.	P.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
15	0·02	0·002	0·40	0·062	0·061
16	0·46	0·062	0·64	0·034	0·008
17	0·84	0·164	0·31	0·035	0·025

the analyses being given in Table III. The test bars were machined from normalised steel rod, 0·75 in. in diameter. It was found that the 0·02 per cent. carbon steel gave a deflection curve somewhat different from those obtained on the cast irons. Deflection is at first fairly rapid and then slows up, finally becoming rapid again. A possible explanation for this was found when a section from the parallel part of the bar was examined under the microscope after test. This showed that crystal growth had taken place to a very considerable extent. It appears probable that, as the crystals became larger, the resistance of the bar to deflection at high temperatures was increased. This conclusion is supported by the results obtained on the 0·84-per cent. carbon steel; little grain growth occurred and the deflection curve of this bar is smooth. The bar scaled rapidly and the rapid deflection at the end of the test was no doubt due to wastage of the specimen. Examination of the structures of the three bars before and after the test, the latter being taken from the stressed portion of the specimens, showed that grain growth had taken place to a considerable extent in the 0·02-per cent. carbon-steel bar and to a smaller extent in the 0·46-per cent. carbon-steel bar. There was little change in the structure of the 0·84-per cent. carbon steel after the test. When these results are compared with those for the cast irons, it is found that the high-carbon (0·8 per cent.) steel deflected considerably more than any of the cast irons tested, with the exception of those with very coarse graphite structures (large-diameter bars). The medium-carbon (0·4 per cent.) steel has a resistance to deflection comparable with that of a cast iron containing 5·75 per cent. of silicon (0·65 in. diameter bar).

The Rigidity of Austenitic Heat-Resisting Cast Irons at 850 deg. C.—The most important of the recently developed heat-resisting cast irons are the highly alloyed austenitic irons known as Ni-Resist and Nicrosilal. The former contains nickel, copper and chromium, and the latter nickel, silicon and chromium. Both types of iron are made in a range of compositions to suit various conditions of service. Increasing the chromium content usually results in an increased resistance to scaling and growth, but high chromium renders the metal hard and practically unmachinable in the as-cast state. Two irons of each type, with high and low chromium contents, were tested, the compositions for this Series (F) being as given in Table IV.

TABLE IV.—*Compositions of Alloy Heat-Resisting Irons, Series F.*

No.	Total Carbon.	Si.	Mn.	S.	P.	Ni.	Cr.	Cu.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
18	2·51	1·63	0·53	0·073	0·270	16·40	2·51	7·35
19	1·79	5·90	0·76	0·027	0·033	17·15	1·95	—
20	2·23	2·00	0·54	0·029	0·190	15·74	11·95	7·10
21	2·18	4·91	0·49	0·039	0·031	18·65	7·25	—

All the bars were cast in green-sand moulds from metal melted in a coke-fired crucible furnace. The metal was produced from charges consisting of Swedish white iron (3·8 per cent. total carbon), ferro-silicon (40 per cent. silicon), Armco iron and ferro-chromium (70 per cent. chromium, 1·5 per cent. carbon), with small additions of ferro-phosphorus and ferro-man-

ganese. Nickel was added as nickel F shot, and copper scrap was used for additions of this element. In each case the metal was melted down and superheated for 15 minutes before pouring. The as-cast size of the bars was 0·75 in. in diameter.

The resistance of these irons to deflection under load at high temperatures is shown in Fig. 12, on page 99. The higher-chromium bars of each type are more rigid than those lower in chromium. The higher-silicon material offers a greater resistance to deflection than the lower-silicon bars, in both the high- and low-chromium compositions. The rapid deflection of the high-chromium high-silicon iron in the early stages of the test may be due to a change in structure taking place. In the as-cast state the structure is composed of cementite and austenite. Evidence is available that, in irons of this composition, carbide is deposited from the solid solution in the early stages of heating. It is possible that the resistance of the bar to deflection would be reduced while this structural change was taking place. It would appear that irons of this type should be well annealed at a temperature of 850 deg. to 900 deg. C. before being put into service. These tests show that austenite high-silicon nickel irons are more rigid at high temperatures than austenitic copper-nickel irons, and that additions of chromium increase the stiffness of austenitic cast irons at 850 deg. C.

Fig. 13 shows a comparison of the resistance to deflection at 850 deg. C. of a steel (No. 17, Table III), an ordinary good-quality grey cast iron (No. 2, Table I), a high-phosphorus grey iron (No. 12A, Table II), a good heat-resisting iron of the Silal type (No. 3, Table I), a high-silicon iron (No. 6, Table I), and a highly heat-resistant austenitic iron (No. 21, Table IV).

Conclusions.—Many factors influence the resistance to deflection of cast irons at elevated temperatures. Normal engineering irons have little resistance to growth and scaling, and will, of course, fail from these causes under prolonged heating. High-silicon cast irons of the Silal type were found to have a good measure of stiffness at 850 deg. C. Higher-silicon irons (7 per cent. to 9 per cent. of silicon) have an excellent resistance to scaling and growth, and an increased resistance to deflection. These irons would be expected to have a much longer life than straight grey irons under most conditions of high-temperature service. The tests carried out show that such irons are capable of undergoing considerable deflection at 850 deg. C. without fracture. The high-silicon acid-resisting type of iron (14 per cent. of silicon) was found to be very rigid at 850 deg. C. This type of iron is, however, extremely brittle in the cold, and although proved to be relatively ductile at 850 deg. C., would possibly crack if subjected to rapid changes in temperature.

At the temperature at which these tests were carried out, additions of phosphorus were found to be beneficial in increasing the resistance of cast iron to deflection; this was particularly so in the case of the higher-silicon irons. It should, however, be noted that the phosphide eutectic melts at a temperature of approximately 960 deg. C., and at temperatures of this order the presence of relatively small quantities of phosphorus is sufficient to cause almost complete loss of mechanical strength. The austenitic irons, Nicrosilal and Ni-Resist, were found to have a good resistance to deflection at 850 deg. C. As these irons also have a marked resistance to scaling and growth, they are suitable for use under many conditions of service.

Graphite size has an important influence on resistance to deflection at high temperatures. It would appear necessary that grey cast iron for high-temperature service should have as fine a graphite structure as possible. This may be obtained by relatively rapid cooling of the metal from the molten state, or by the use of a low total-carbon content. The thickness of the casting should be kept to a minimum, as thick sections cool slowly and this normally yields a coarse graphite structure. Slight differences in graphite size are, however, of less importance than relatively small changes in composition, *e.g.*, in silicon or phosphorus content. Three plain carbon steels were tested, and it was found that these had less resistance to deflection at 850 deg. C. than many of the cast irons examined.

In using the data obtained from these tests in deciding on the most suitable type of iron for service at high temperatures, the conditions of service must be taken into account. If, for example, the service conditions entail heating the casting slowly to a uniform temperature, it is thought that an iron which is highly resistant to deflection will give better service than one which is less resistant. On the other hand, if the service conditions are such that the casting is subjected to steep temperature gradients, then it is possible that some stiffness must be sacrificed, and a less rigid iron will be better able to withstand these conditions. It is known, for example, that the high-silicon cast irons, shown to be very resistant to deflection at high temperatures, are susceptible to cracking under conditions where temperature gradients exist, while hematite irons with a coarse graphite structure give good service under considerable and rapid changes in temperature.

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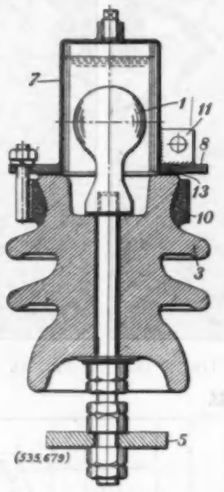
ELECTRICAL APPARATUS.

535,679. Protective Spark Gap. The British Thomson-Houston Company, Limited, of London, and F. H. Clough, of Clay Cotton. (1 *Fig.*) January 29, 1940.—The spark gap is designed primarily for use in protecting terminal apparatus at power stations and the construction is such that it is protected from weather conditions and the danger of birds causing breakdown. Furthermore, it is cheap to produce, and only requires a minimum of replacement after it has been subjected to breakdown conditions. A sphere 1 is mounted on a bolt passing through the centre of a porcelain insulator 3 and secured to an earthed supporting frame 5. The end of the insulator adjacent to the sphere is countersunk to provide the requisite insulating distance between the sphere and



a surrounding cylinder 7 which is supported on the insulator. The enclosing cylinder consists of a thin-walled metal cap, closed at its upper end, which is placed over the sphere and is secured at its open end to a metal ring 8 which is bolted down to a ring 10 cemented to the insulator. The circuit to be protected is connected to a terminal tab 11 secured to the ring. The metal cap is filled with oil and is lined with paper. The paper lining consists of several layers of thoroughly dried paper which is protected from moisture by the metal cap and the oil filling, a gasket 13 being provided between the ring and the insulator. The use of a sphere ensures that the electric field between it and the surrounding metal cap is uniform and consequently can be accurately controlled and the breakdown value of the gap predetermined. In addition, rapid breakdown is assured. (*Accepted April* 17, 1941.)

LIFTING AND HAULING APPLIANCES.

535,748. Lifting Jack. Lake and Elliott Limited, of Braintree, and H. R. Barrett, of Chelmsford. (6 *Figs.*) November 17, 1939.—The invention is a lifting jack in which the reaction of the load is distributed over the sides of the body of the jack so as to give increased strength and better balance than in previous constructions. A pair of vertical channels 1 are secured to a base so that their flanges face each other and form a box construction having slots on opposite sides. Within the channels slides a bracket 5 with projections 6 and 7 protruding through the slots. One extension 6 carries a lifting toe 8 and rollers 9 and the other extension 7 is fitted with rollers 10. The latter take the reaction of the load during lifting, and are positioned above the rollers 9 for this purpose. The projections 6 and 7 are drilled to take transverse bolts for securing bifurcated lugs 13 and 14, respectively. The transverse bolts also carry the rollers 9 and 10. The upper ends of the lugs 13 on the projection 6 constitute the lifting toes 8 to carry the load. Through the bracket 5 passes the lifting screw, which is carried at its upper end by a thrust bearing 20 on a cover for the upper end of the box structure formed by the channels 1. Below the lifting bracket 5 is a

Fig.1.

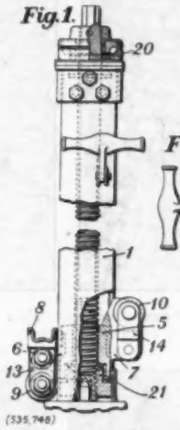
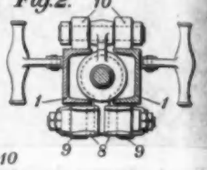


Fig.2.



threaded nut 21, the upper surface of which is formed with a spherical recess to accommodate a co-operating surface on the under-side of the bracket. An upstanding pin in the foot projects into a recess in the end of the lifting screw, the upper end of which passes through the top of the cover and is squared to take a ratchet type spanner. (*Accepted April* 21, 1941.)

MACHINE TOOLS AND MACHINE-SHOP EQUIPMENT.

535,660. Micrometer Adjustment Device. Kapella, Limited, of Leicester, R. E. Reason and T. W. Clifford, of Leicester. (9 *Figs.*) October 12, 1939.—The microscope is carried by a fixed base, and a carriage C for the work runs on rollers working in guides on the upper surface of the base. A micrometer D is mounted on the carriage with the thrust spindle horizontal. Within the carriage lies a stop tube E surrounded by a compression loading spring. Within the stop tube is a thrust rod F, one end of which carries a shoulder F^1 which engages a collar threaded into a hollow lock-nut F^2. The latter, in turn, is threaded on to the end of the stop tube. The lock-nut has a forked end which engages behind a flange on the micrometer spindle and acts to prevent unintentional separation of the micrometer spindle from the lock-nut, though allowing slight back-lash. In the stop tube E is a longitudinal slot into which open several notches. A fixed bracket on the base carries a fixed abutment B^2 and a stud B^3 which runs in the slot and can enter any one of the notches. Normally the stop tube is fixed by the stud B^3 in the end notch and the loading spring urges the flanged end of the micrometer spindle

Fig.1.

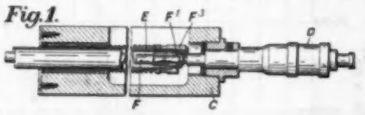
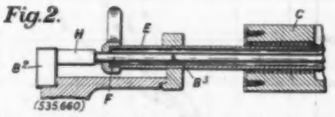


Fig.2.



against one end of the thrust rod F. The other end is thus pressed against the fixed abutment B^2. Before inserting a gauge block H, a reading is taken on the micrometer and the stop tube is turned to bring the stud B^3 into the longitudinal slot. The tube is now moved away from the abutment B^2, first taking up the slight back-lash and then moving the whole carriage C, the movement continuing until the stud B^3 registers with the notch which corresponds roughly to the spacing which is to be effected by the gauge block H, and the stop tube is finally rotated so that the stud engages in the chosen notch. The gauge block H is next inserted between the fixed abutment B^2 and the thrust rod F, the required slight movement of which is permitted by the back-lash. The thrust rod F is thus accurately positioned and its movement is transmitted directly through the micrometer to the carriage C. Should the gauge block H become dislodged, the loading spring will merely cause the carriage and micrometer to move towards the fixed abutment B^2 until the shoulder F^1 abuts against the adjacent collar within the stop tube, *i.e.*, through the small distance permitted by the back-lash, and the load of the spring will be taken by the stop tube. (*Accepted April* 17, 1941.)